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Sewer and drain swabbing as a means of investigating salmonellosis

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SUMMARY

The use of gauze swabs in drains or sewers to clarify the path followed by a salmonella from source to human host has been reviewed in the light of experience gained in Cardiff over 15 years. This period has seen a marked change in attitudes to salmonella epidemiology in that infected food is now regarded as of greater importance than infected food handlers. In these 15 years, butchers, abattoirs and knackers' yards, markets and bakehouses have been monitored. In the bakehouse survey the existence of staff infection was demonstrated by sewage examination. Sewage investigation has also been used to show frequent entry of salmonellas into households in a residential estate. The estate was carefully chosen to exclude salmonellas from industrial sources and shops. The frequent finding of infection in this sewage implies that a commonly consumed heavily infected food item is involved. The wide range of serotypes isolated suggests an animal usually fed on infected animal feed. Poultry and pigs are put forward as animals liable to spread salmonellosis to man.

It is hoped that clarification of the salmonella pathway may eventually lead to measures likely to prevent the transmission of infection to man. It is also suggested that swabs placed in abattoir drains serve as an economical method of obtaining warning of a persistent build-up of contamination. The persistence of a serotype in an abattoir is not infrequently followed by human infection.

INTRODUCTION

The use of gauze swabs (Moore, 1948) for investigating salmonellosis in food premises was suggested by Moore, Perry & Chard (1952). In Cardiff, in 1955, such swabs placed in drains were employed to show the presence of *Salmonella typhimurium* in the environment of a butcher's shop suspected of selling infected meat. This incident led us to initiate a swab survey of bakehouses in 1955–7. The investigation demonstrated the entry of salmonellas in raw ingredients of confectionery manufacture and the existence of minor or latent infections in members of bakery staff (Harvey, 1957; Harvey & Phillips, 1961). The bakery survey led to a similar study of Glamorgan abattoirs in 1957–9. In this investigation, phage-typing of strains of *S. typhimurium* enabled a detailed comparison to be made between abattoir and human isolations. The timing of recovery of the same phage-

types from abattoir and man strongly suggested a causal association (Harvey & Phillips, 1961). Gauze swabs also proved of value in demonstrating the presence of *S. typhimurium*, type 12, in the environment of 15 out of 54 shops during an outbreak of salmonella food poisoning in Cardiff in 1960. Human infections in the city tended to be clustered round shops from which *S. typhimurium*, type 12, was isolated (Harvey, Price, Bate & Allen, 1963).

It is convenient to consider salmonella epidemiology in terms of a cycle. The importance of the various parts of the cycle are open to conjecture and argument. If we suggest, however, that one of the pathways travelled is:

Animal food → Animals on farms,
→ Animals at abattoirs,
→ Meat wholesalers and retailers,
→ Man,
→ Sewage,
→ Sewage polluted water,

a number of situations emerge which are worth monitoring by the swab technique.

The salmonella content of animal feed requires continuous investigation for comparison with isolations from animals, abattoirs and man, but is outside the scope of the present study.

METHODS

The technique used in Cardiff to isolate salmonellas from swabs has recently been described in detail (Harvey, Price, Foster & Griffiths, 1969). We shall, therefore, confine ourselves to general principles in this paper.

Drain and sewer swabbing is a useful means of salmonella surveillance. It is not as sensitive in abattoir investigation as examination of caecal faeces from slaughtered animals. In human surveillance it is more rewarding than relying on records of clinical food poisoning. It requires an efficient isolation technique.

Important technical factors are: (*a*) length of exposure of swabs to sewage; (*b*) enrichment; (*c*) selective media; (*d*) secondary enrichment; (*e*) search for multiple serotypes in single samples.

Length of exposure of swab to drain or sewage flow

Exposure may vary from mere wiping the swab along the drain or sewer surface (Harvey & Phillips, 1955), to leaving it in the flow for up to 7 days. The decision which method to use is administrative rather than technical. If rats are inclined to remove swabs, the wipe technique may often be valuable. If two visits to an area each week are not convenient, the 7-day period is useful. A recent survey on human sewage employed both techniques (Harvey *et al.* 1969).

A heavily soiled swab may require 48 hr. incubation in selenite F to produce a positive result (Guth, 1916; Leifson, 1936; Harvey, 1965), whereas a 'wipe' swab may produce a pure culture of salmonellas from a 24-hr. plating. We seldom sub-culture from selenite at 48 hr. nowadays as secondary enrichment from selective

agars has replaced this technique. In early sewer surveys, however, multiple subculture from selenite F broth was an integral part of salmonella isolation (Harvey & Phillips, 1955).

Enrichment

The usual fluid media chosen in this country are selenite F broth, balanced tetrathionate (Knox, Gell & Pollock, 1943), Kauffmann–Muller tetrathionate (Heard, Jennett & Linton, 1969) and the malachite green, magnesium sulphate broth of Rappaport, Konforti & Navon (1956). The selenite and tetrathionate broths can be made to function extremely well at 43° C. The malachite green medium has to be used at 37° C. In Cardiff we have for many years had a preference for selenite F broth + $1/10^6$ brilliant green (final concentration). This quantity of dye does not prevent the use of 43° C. for incubation. Commercial selenite brilliant green broth which has a higher concentration of dye may not allow such a high incubation temperature to be used. There is now reasonable confirmation from several parts of the world that incubation temperatures above 37° C. and not higher than 43° C. aid salmonella isolation. The subject has recently been discussed (Harvey & Price, 1968).

In Cardiff, we culture the entire swab in the jar in which it is received. It is merely covered with single strength enrichment medium and incubated at 43° C. This saves relabelling samples. We have always favoured culturing the whole swab. Large inocula in enrichment media usually benefit isolation (Harvey, 1965). Many workers, however, prefer the use of dilutions of swab fluid.

Any single enrichment medium, if inoculated with material containing two serotypes, may have a bias towards allowing more rapid multiplication of one of them. This problem is being currently studied on paired naturally infected samples. It is highly relevant to the conduct of unbiased surveys.

Plating media

The plating media favoured are: brilliant green MacConkey agar (Wilson & Blair, 1931; Harvey, 1956), Oxoid brilliant green agar, deoxycholate citrate agar, S.S. agar (Oxoid or Difco) and de Loureiro's (1942) modification of Wilson & Blair's bismuth sulphite agar. We find brilliant green MacConkey the best all round medium, closely followed by Oxoid brilliant green agar. Deoxycholate citrate agar is essential for optimum isolation of *S. dublin*. Wilson & Blair's medium is necessary for easy recognition of subgenus III salmonellas (Harvey, Price & Dixon, 1966).

Secondary enrichment

Growth is removed by a short throat swab from deoxycholate citrate agar plates, passed through a modified Craigie tube (Harvey & Price, 1967*a*) and subcultured to brilliant green MacConkey. Secondary enrichment is absolutely necessary in drain and sewer swab investigations if selenite F is used for primary enrichment. The combination of selective agars described here allows strains of *S. dublin* to be recovered. In the original description of the method, difficulty was experienced

with this serotype. The technique is also excellent for separating pseudomonas from salmonellas (Ino & Graber, 1955).

Search for multiple serotypes

Any drain swab is potentially contaminated with several salmonella serotypes. Although the number of serotypes isolated from a sample is a function of the number of colonies picked (Harvey & Price, 1967*b*), multiple picking will *not* always reveal some of the epidemiologically interesting serotypes. This was found in the isolation of salmonellas from Indian crushed bone. On one occasion 50 colonies were picked from an infected sample. Only one serotype was found. The serological technique described by Harvey & Price (1967*b*) allowed isolation of two further serotypes and this technique is now used as a routine. Unless employed, valuable information will be lost. The method has recently been adapted to the more specific isolation of *S. typhimurium* from Argentine bone (R. W. S. Harvey & T. H. Price, unpublished).

RESULTS

Animals at abattoirs

The original investigation of Cardiff abattoir lasted 3 years. Monitoring of this slaughter house continued, however, and only ceased with the closure of the premises in 1967. Drains were selected which gave some information on the type of animal bringing salmonellas into the abattoir. Clear-cut information was rarely obtained, but in a period of high incidence of *S. typhimurium*, phage type 12*a*, and *S. brandenburg*, positive results were obtained for many weeks in the drain receiving material from slaughtered pigs and not from the drain monitoring cattle and sheep only. In Barry abattoir and Pontypridd abattoir, it was possible to sample areas solely concerned with pig slaughter. In the former establishment, 20 % of swabs were positive over a 6-year period, in the latter, 30 % over 12 months. In a recent survey in the new Cardiff abattoir, 10 % of 1000 pig caecal faeces and 5 % of 1000 caecal swabs contained salmonellas. The amount of faecal material on a caecal swab is approximately 0·6 g. (J. Morgan, personal communication). Many serotypes found in pigs were also present in raw ingredients of locally distributed animal food.

The range of serotypes isolated in the years 1957–67, is given in Table 1 in historical order of isolation. This arrangement produces an inverted step-like effect and suggests the seeding of farm animals each year with new serotypes possibly from animal feed ingredients.

The isolation of Arizona 26:29–30 in 1965 is of interest. This serotype is pathogenic to sheep in Europe and has been isolated from human infections in sheep-herding tribes of Red Indians in the U.S.A.

It will be noted that *S. typhimurium* and *S. dublin* dominate the serotype pattern. The former, however, was not isolated for the first 20 months of the survey. Is the relative dominance of *S. typhimurium* in abattoirs of comparatively recent origin? *S. dublin* was not found in Cardiff abattoir in 1960–62. As *S. dublin* is endemic in South Wales, we suspect that this was due to a technical artifact and

that the increased number of isolations of *S. typhimurium* interfered with the recovery of *S. dublin*. A slight change in technique possibly contributed to the reappearance of *S. dublin* in 1963.

Table 1. *Cardiff abattoir*

(Range of serotypes isolated.)

Salmonella serotype	Year 1957–67											Other isolations
	57	58	59	60	61	62	63	64	65	66	67	
S. dublin	12	7	1	—	—	—	6	11	10	29	14	—
S. senftenberg	1	—	1	—	—	—	—	—	—	—	—	—
S. meleagridis	1	2	4*	—	—	—	—	1	—	—	—	—
S. anatum	3	—	4	—	—	1	—	—	—	—	1	—
S. bovis-morbificans	2	—	—	—	—	—	—	—	1	—	—	—
S. enteritidis	5*	1	1	2	—	—	1	1*	1*	1	1	—
S. thompson	4	—	1	—	—	—	—	1	—	—	—	—
S. muenchen	—	3	1*	—	—	1	—	—	—	—	—	—
S. kiambu	—	1	—	—	—	—	—	—	—	—	—	—
S. derby	—	4*	—	—	—	—	—	4	1	1	—	—
S. typhimurium	—	16*	31*	38*	3	13*	23*	18	10	24	12	—
S. kentucky	—	—	2	—	—	—	—	—	—	—	—	—
S. abony	—	—	1	—	—	—	—	—	—	—	—	—
S. weltevreden	—	—	1	—	—	—	—	—	—	—	—	—
S. newport	—	—	—	1	—	—	—	—	—	1	—	—
S. give	—	—	—	2	—	—	—	1	—	—	—	Pigs and butchers' equipment 1960
S. brandenburg	—	—	—	4	4	—	—	51*	4*	—	—	Butchers' equipment 1964
S. taksony	—	—	—	—	3	—	—	—	—	—	—	—
S. heidelberg	—	—	—	—	1*	4	—	—	—	—	—	—
S. paratyphi B, var. java	—	—	—	—	—	2	—	—	—	—	—	Type Battersea
S. luke	—	—	—	—	—	1	—	—	—	—	—	—
S. menston	—	—	—	—	—	—	1	—	—	—	—	—
S. agama	—	—	—	—	—	—	—	1	—	—	—	Local abattoir, man and butchers' equipment 1963
S. chester	—	—	—	—	—	—	—	2	—	—	—	—
S. bredeney	—	—	—	—	—	—	—	3	—	—	—	—
S. panama	—	—	—	—	—	—	—	3	—	—	—	—
S. poona	—	—	—	—	—	—	—	1	—	1	—	—
S. uganda	—	—	—	—	—	—	—	1	—	—	—	—
S. havana	—	—	—	—	—	—	—	—	5	—	—	—
Arizona 26:29–30	—	—	—	—	—	—	—	—	3	—	—	—
S. stanley	—	—	—	—	—	—	—	—	13*	3	—	—
S. takoradi	—	—	—	—	—	—	—	—	—	1	—	—
S. oranienburg	—	—	—	—	—	—	—	—	—	1	—	—
S. eimsbuettel	—	—	—	—	—	—	—	—	—	1	—	—
S. indiana	—	—	—	—	—	—	—	—	—	—	1	—

* Local infection in man due to same serotype or phage type in same year.

The remarks column in Table 1 amplifies information concerning certain serotypes. Asterisks denote the occurrence of human infections in the same year as an isolation from the abattoir—often within a few weeks.

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Table 2. *Correlation of human and abattoir isolations*

(All Glamorgan abattoirs included.)

Serotype	Year of incident	Month 1	2	3	4	5	6	7	8	9	10	11	12	Abattoir isolations: Cattle drain	Pig drain	*Incidents England and Wales	*Rank of importance in England and Wales in year
S. meleagridis	1958	.	.	.	.	+	.	.	.	.	.	.	.	.	.	4	.
S. derby	1958	.	.	.	.	.	.	.	.	+	.	.	.	Sept. 1958	.	58	7
S. derby	1962	.	.	.	.	.	.	.	+	.	.	.	.	.	Sept. 1962	11	.
S. typhimurium, 1 var. 5	1959	.	.	.	.	.	.	.	.	.	+	.	.	Oct. 1959	.	.	.
S. heidelberg	1959	.	.	.	.	.	.	.	.	.	+	.	.	.	.	182	4
S. heidelberg	1961	.	.	.	.	.	.	.	.	.	+	.	.	.	Jan. 1962	289	2
S. typhimurium, 2 (12)	1960	.	.	.	.	.	.	+	+	+	+	.	.	July 1960	Sept. 1960	.	.
S. typhimurium, 2 (12*a*)	1962	.	.	.	.	.	.	.	.	.	+	+	+	.	Oct. 1962	.	.
S. typhimurium, 2 (12*a*)	1963	.	.	.	+	+	+	+	+	+	+	+	+	May 1963	April 1963	.	.
S. typhimurium, 4	1963	.	.	.	.	.	+	.	.	.	.	.	.	.	June 1963	.	.
S. agama	1963	.	.	.	.	.	.	+	.	.	.	.	.	.	July 1963	12	.
S. brandenburg	1964	.	.	.	.	.	+	+	+	+	+	+	.	.	.	312	2
S. stanley	1965	.	.	.	.	.	.	.	+	+	+	+	.	.	.	50	7
S. typhimurium, U 163	1967	.	+	.	.	.	.	.	.	.	.	.	.	Feb. 1967	.	.	.
No. of occasions same serotype or phage-type found in same month in abattoir and man		.	1	.	1	2	3	4	5	5	8	4	2	.	.	.	.

* Reports (1959), (1960), (1962), (1963), (1964*a*), (1965), (1966).

The pattern of salmonellosis in Cardiff abattoir is sometimes representative of national trends. This is demonstrated in Table 2 in which the occurrence of the same serotype or phage type in the same month in abattoir and in man is charted. Short term abattoir drain surveys fail to provide evidence of seasonal effects on environmental contamination. A long-term survey, however, will give information on such trends. This is illustrated in Table 3, which is arranged in quarters of the year. The third quarter shows maximum abattoir contamination. A seasonal effect on monthly correlations of serotypes isolated from abattoir and man is also evident in Table 2.

Table 3. *Cardiff abattoir*

(Swabs positive at different seasons of year, 1957–67.)

Quarter of year	Number of swabs examined	Number positive
January–March	280	83 (30)
April–June	246	95 (39)
July–September	282	150 (53)
October–December	273	127 (47)

Figures in parentheses are percentages.
Highest percentage of positive swabs is obtained in third quarter of year.

Table 4. *Cardiff abattoir*

(Annual incidence of positive swabs 1957–67.)

Year	Percentage of swabs positive	Ratio of ovine: bovine species
1957	33	3:1
1958	31	3:1
1959	59	6:1
1960	72	4:1
1961	11	4:1
1962	25	4:1
1963	44	4:1
1964	57	6:1
1965	57	7:1
1966	51	6:1
1967	54	3:1

Sheep are the dominant species in this abattoir. Changes in ratio between sheep and cattle show no correlation with percentage of swabs positive.

Table 4 records changes in annual incidence of positive swabs in the abattoir for the years 1957–67. It will be noted that the annual percentage of positive swabs varies considerably. There was no correlation between such changes and alterations in the ratio of sheep to cattle slaughtered. In Cardiff, sheep dominate the animals killed. Report (1964*b*) showed a correlation between abattoirs with high environmental contamination and the proportion of cattle slaughtered. In general, abattoirs killing a high proportion of cattle and a low proportion of sheep were heavily contaminated.

Meat wholesalers and retailers

Our main study of this point on the salmonella pathway has been conducted at Cardiff Central Market. This is a two-level structure comprising a gallery and ground floor. The gallery houses a pet meat stall and several stalls selling pet animals. Terrapins and tortoises are included in animals for sale. The ground floor consists of premises selling fish, fruit and vegetables, meat, poultry, dairy produce and flowers. Drains running along north and south aspects of the ground floor were

Table 5. *Cardiff covered meat market*

(Range of serotypes isolated.)

Salmonella serotype	Year 1963–68						Remarks
	63	64	65	66	67	68	
S. typhimurium	10	3	1	1	4	—	—
S. kingabwa	1	—	—	—	—	—	—
S. jerusalem	1	—	—	—	—	—	—
S. richmond	2	—	—	—	—	—	—
S. eastbourne	1	—	—	—	—	—	Prevalent in man 1963
S. derby	1	—	1	—	—	—	Infection in man 1965
S. dublin	—	1	—	—	—	—	—
S. clifton	—	1	—	—	1	—	Subgenus II
S. brandenburg	—	1	—	—	1	—	Prevalent in man 1964
S. oranienburg	—	1	—	1	—	—	—
S. senftenberg	—	—	1	—	—	1	—
S. paratyphi B, var. java, 1 var. 6	—	—	1	—	—	—	Outbreak in N. Wales 1959, 1964
S. bovis-morbificans	—	—	1	—	—	—	—
S. stanley	—	—	4	—	1	—	Prevalent in man 1965, 1967
S. enteritidis, essen	—	—	1	—	—	—	—
S. liverpool	—	—	—	2	—	—	Infection in man 1966
S. havana	—	—	—	1	—	—	—
S. panama	—	—	—	5	1	—	Infection in man 1967
S. abony	—	—	—	1	1	—	—
S. schwarzengrund	—	—	—	1	—	—	Infection in man 1966
S. bredeney	—	—	—	1	—	—	—
S. kiambu	—	—	—	1	—	—	—
S. indiana	—	—	—	4	—	—	Infection in man 1967
S. sofia	—	—	—	—	1	—	Subgenus II
S. newport	—	—	—	—	2	—	Infection in man 1967
S. sheffield	—	—	—	—	1	—	—
S. poona	—	—	—	—	1	—	—
S. javiana	—	—	—	—	1	—	—
Arizona 26:32–21	—	—	—	—	1	—	Subgenus III. Human infection, U.K. 1966
S. manhattan	—	—	—	—	1	—	—
S. reading	—	—	—	—	2	—	Infection in man 1967
S. livingstone	—	—	—	—	—	1	—

sampled over 6 years. The salmonella isolations from swabs placed in these drains are given in Table 5. The remarks column records information on certain serotypes considered relevant to their epidemiology. Certain salmonellas appear in Table 5 not found in Table 1 in the same time period (*S. eastbourne*, *S. liverpool*, *S. schwar-*

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zengrund), although they were found in overt infection in man in the same year. The market sells poultry and imported meat. This could explain isolation of different serotypes from those found in the abattoir. The isolation of *S. paratyphi* B, var. java phage-type 1 var. 6, is interesting as this organism was responsible for sharp outbreaks of human infection in North Wales in 1959 and 1964. These outbreaks were probably from an animal source. The slime layer test is done as a routine on all strains of *S. paratyphi* B isolated from abattoirs and feeding stuffs.

Subgenus II strains found in this market may be due to the presence of animals carrying such organisms (tortoises and terrapins). Alternatively they may have gained entry to the U.K. in imported animal food from countries where this subgenus is common (Brede, 1964).

Table 6 records a parallel investigation on surfaces of butchers' equipment using broth moistened 'wipe' swabs (Harvey & Phillips, 1955). They were taken in a period of high incidence of human salmonellosis. The table is self explanatory and emphasizes danger of cross-contamination of meat in butchers' premises. The majority of samples were taken from three large wholesale butchers in Cardiff.

Table 6. *Equipment surfaces in retail and wholesale butchers sampled by 'wipe' swab technique June* 1963–*January* 1964

Surface found positive	Isolation
Sausage machine	*S. typhimurium*, type 12*a*
Fat trimming table (wood)	*S. agama*
Mincer	*S. agama*
Mincer	*S. agama*
Faggot preparation table (marble topped)	*S. typhimurium*, type 12*a*
Preparation table (wood)	*S. typhimurium*, type 12*a*
Inside surface of refrigerator	*S. agama*
Mincer	*S. agama*
Galvanized sink	*S. agama*
Unspecified surfaces (7)	*S. agama*: 5 isolations *S. typhimurium*, type 12*a*: 2 isolations

Total surfaces sampled	= 305,
Isolations of *S. typhimurium*, type 12*a* from Man, June 1963–January 1964	= 41,
Isolations of *S. agama* from Man, June 1963–January 1964	= 1.

During this period *S. typhimurium*, phage type 12*a*, was isolated on 23 occasions from Cardiff abattoir and on 21 occasions from the pig area drain in Barry abattoir. Both establishments supplied meat to the wholesale butchers investigated. *S. agama* was found in the pig area drain in Barry abattoir in July 1963. The swab from which it was isolated also contained *S. typhimurium*, type 12*a*. The separation of these antigenically similar serotypes was made by the serological method described by Harvey & Price (1967*b*).

Man, sewage, sewage polluted water

Salmonellosis in man in our area is at a low ebb. The numbers of overt infections. diagnosed each year in Cardiff from 1963 to 1968 were: 160, 74, 80, 42, 111 and 57 As the medical importance of any salmonella focus in an area can best be judged

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Table 7. *Serotypes isolated from human sewage*

	1967								1968						
Serotype	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July
S. paratyphi B	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
S. brandenburg	+	+	+	+	−	−	−	−	−	−	−	−	−	−	−
S. dublin	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−
S. give	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−
S. anatum	+	+	−	−	+	+	+	−	−	+	−	−	−	−	−
*S. kraaifontein**	−	+	−	−	−	−	−	−	+	−	+	−	+	−	−
S. enteritidis	−	+	−	−	−	−	−	+	−	−	−	−	−	−	−
S. typhimurium	−	+	−	−	−	−	−	+	−	−	−	+	+	+	−
S. oranienburg	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−
S. schwarzengrund	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−
S. stanley	−	−	+	+	+	+	−	−	−	−	−	−	−	−	−
S. manhattan	−	−	+	−	+	−	−	−	−	−	−	−	−	−	−
S. newport	−	−	+	+	+	−	−	−	−	−	−	−	−	−	−
S. panama	−	−	−	+	+	−	+	+	−	+	−	+	−	+	+
S. bredeney	−	−	−	−	+	+	−	−	−	−	−	−	−	+	−
S. indiana	−	−	−	−	+	+	+	+	+	−	−	−	−	+	−
S. senftenberg	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−
S. derby	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−
S. galiema	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−
S. kentucky	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−
S. livingstone	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−
S. fischerkietz	−	−	−	−	−	−	−	−	−	−	−	−	−	+	+
S. duisburg	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−
*S. bleadon**	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+
*S. uphill**	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+

The sewage was derived from an estate of 4000 persons. Neither industry nor butchers' shops were located in the area investigated. Surface water was found to be negative for salmonellas.

* Subgenus II.

by its impact on man, it was thought necessary to examine local human salmonellosis by more sensitive means than mere records of clinical infection.

From several years examination of samples of the river Taff, which drains a densely populated part of North Glamorgan, we came to the conclusion that overt salmonella infection represented only a very small proportion indeed of total human infection in the area. It was essential to be certain that river isolations were not coming from industrial effluent. In 1967, therefore, we began a detailed examination of human sewage from an estate of 4000 persons (Harvey *et al.* 1969). The use of selected sewage examination had previously been of value in the bakery survey (Harvey & Phillips, 1961).

The estate was purely residential. It was situated on a hillside where sewage back flow was impossible. The sewage from other residential areas could not possibly enter the drainage investigated. It contained neither industry nor retail butchers' shops. Parts of the area contained no shops at all. Samples of surface water were negative for salmonellas. Samples of sewage from the main drain of the estate were consistently positive. Points were chosen spreading back into the branches of the sewerage system. One sampling point took sewage from 1000 persons. The results of the survey covering the period May 1967–July 1968 are presented in Table 7. From the sampling point monitoring 1000 people, 12 different serotypes were isolated over a year. This gives some idea of minimum human infection/1000 p.a. If we exclude *S. paratyphi* B, salmonellas were isolated from the estate on 44 of 54 sampling occasions. These organisms, therefore, regularly reach man. The serotype range was wide and several exotic species were isolated, suggesting that salmonellosis in man sometimes starts outside the United Kingdom. Subgenus II strains were occasionally found. It would seem that a frequently infected and regularly consumed vehicle carries salmonellas into households. We consider poultry and pig products possible sources of infection. These animals frequently consume infected feed.

DISCUSSION

Drain swabbing in Cardiff covered the years 1955–69. The early part of this period witnessed a major change in epidemiological attitudes to salmonellosis. Realization came, very gradually, that contaminated food ingredients were sources of infection of greater importance than human excreters. This point was not made without opposition. It was largely due to the work of Thomson (1953). The use of drain swabs served to emphasize this (Harvey, 1957). By this means we were able to chart entry into, persistence in and exit of serotypes from situations such as bakeries, abattoirs, knackers' yards, butchers, retail markets and human sewage.

The development of phage-typing of strains of *S. typhimurium* by Anderson & Wilson (1961) immensely increased accurate comparison of veterinary and human isolations. *S. typhimurium* is by far the most important salmonella species common to man and animals. Comparative studies became of vital importance with the demonstration of transferable drug resistance (Anderson & Lewis, 1965; Anderson,

1968). The drain swab technique increased opportunities for contrasting food, animal and human salmonellosis.

Experience suggests that the abattoir drain swab is an economical check on appearance and continued persistence of a serotype in a slaughter house. Persistence is not infrequently followed by infection of man (Table 2). Warm weather periods are particularly dangerous, and forewarning of a build-up of infection could allow application of intensive hygienic measures.

It has been asked if sewer swabbing could be of value in an epidemic to clarify the origins and means of spread of infection. We do not think that this technique, *per se*, can help greatly to control an established outbreak. We believe that proper interpretation of results already obtained may ultimately serve to check the passage of salmonellas from animal to man. We consider it logical to think of the origin of salmonellosis in terms of the initial or, at least, a remote origin. An epidemic caused by what is termed an exotic serotype has an exotic source. The finding of an outbreak serotype in a butcher's shop environment is surely evidence of mode of spread (Harvey *et al.* 1963). The clustering of human infections round a series of shops shown to have the relevant serotype on the premises indicates advisability of hygiene checks in the area. This is not beyond the powers of health authorities.

The discovery that a wide range of salmonellas frequently reach man (Harvey *et al.* 1969), suggests that vehicles frequently infected with many serotypes bring infection into households. Such vehicles must be food that is commonly consumed. The increased sale of broiler chickens has recently been recorded (Gould & Rhodes, 1969). These animals are of interest in that they are frequently fed on infected animal feed.

It is usually maintained that, as *S. typhimurium* and *S. dublin* are seldom found in animal feed ingredients, feeding stuffs play little part in transmission of these two serotypes. This may be so. Few would deny, however, that these two species are frequently found in animal intestines on the way from abattoir to rendering plants concerned with manufacture of products destined for animal food. How do we reconcile this with their comparative rarity in home produced meat and bone meal? By careful technique, *S. typhimurium*, phage-type 32, was found in 4/12 samples of bone meal associated with a large outbreak of food poisoning in Scotland. The Cardiff laboratory was responsible for three of those isolations. Isolating *S. dublin* in the presence of more vigorously growing salmonella species is not always easy. This serotype can be easily inhibited by brilliant green, it is poorly isolated on Wilson & Blair (1931) medium and the use of tetrathionate, commercial selenite brilliant green and malachite green magnesium sulphate enrichment media can often prevent its isolation. Selenite F broth subcultured to deoxycholate citrate agar is the optimum means of recovery. Epidemiological interpretation of failure to isolate this serotype must be treated with reserve.

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