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Salmonellae and shigellae in a group of urban South African Bantu school children

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INTRODUCTION

In South Africa, as elsewhere, salmonellosis and shigellosis are recognized public health problems. These infections are usually claimed to predominate in the under-privileged section of the population. In view of this, Bokkenheuser & Richardson (1960) examined at regular intervals a group of rural Bantu school children living under primitive conditions approximately 13 miles from Rustenburg, a town 80 miles west of Johannesburg. Water was obtained from shallow, heavily infected surface wells. Medical clinics were not available within 8–10 miles. Many of the children were infected with salmonellae and shigellae and it was concluded that every child experienced at least one annual infection with these pathogens. Many had multiple infections.

A similar study was undertaken in a group of periurban Bantu school children from poor though economically somewhat better homes in the Witkoppen area about 15 miles north of Johannesburg (Richardson & Bokkenheuser, 1963). The water was unsatisfactory bacteriologically, but a clinic was available one morning per week. Among the children examined the prevalence of salmonellae and shigellae was only slightly lower than among the children in the Rustenburg district and, once again, it appeared that all children experienced at least one annual infection, and many of them several infections.

This paper records a third study among Bantu school children living under urbanized conditions in a Johannesburg township with excellent water and ample clinic facilities.

MATERIAL AND METHODS

Two schools, situated in the Dube township, were chosen for this investigation. The township belongs to the Soweto complex; a housing scheme built by the Government, Municipality and other bodies, to accommodate a population of 480,200 employed in various walks of life in Johannesburg. Soweto is about 15–20 miles south-west of the centre of the city and essential services are administered by the Johannesburg Municipality. Piped water from the Rand Water Board is available in each house. A water-borne sewerage system serves both schools and the homes of the children. Clinics and Baragwanath Hospital (2300 beds) are within easy access.

According to Dr A. R. P. Walker of this Institute, although the diet of the children varies from family to family, the following may be regarded as fairly representative. *Breakfast* (taken about 7 a.m.): soft porridge (maize or 'Kaffir corn'), with sugar but seldom with milk; occasionally sour porridge (*magou*); half a slice of bread with margarine, butter or peanut butter, or sometimes jam; tea with sugar and condensed milk (occasionally fresh milk). *Mid-morning* (at school, 11 a.m.): fat cakes, or doughnuts (bought locally), one slice of polony occasionally. *Lunch* (after school, 3 p.m.): 'stiff' porridge, soup (beans, or other vegetables). *Evening meal* (8 p.m.): 'stiff' porridge, meat or occasionally fish, vegetables, and tea, usually with condensed milk. According to season, fruit is consumed fairly frequently, usually at weekends. Speaking generally, the diet consumed is adequate, both with regard to calories and gross protein; it is low in animal protein and fat. According to orthodox recommended allowances, it is low in certain mineral elements (e.g. calcium), and certain vitamins (e.g. B complex and D).

For comparison with the two previous studies, 130 children were randomly selected, fifty-six, aged between 7 and 10 years, from a primary school called Sizaneni, and seventy-four, aged 11–18 years, from a junior school, Sholom Manne. The schools are within half a mile of each other.

Faeces from the children were examined 8 times during the year at fairly regular intervals. On each occasion oral temperatures were taken and the consistency of the stools noted. The specimens were then planted on S.S. agar and in selenite F medium, and a portion was placed in a sterile bottle for parasitological examination. Plates and enrichment media were taken to the laboratory in Johannesburg and incubated overnight. The following morning, a loopful from the selenite F medium was planted on S.S. agar and incubated. From each plate three non-lactose-fermenting colonies, if present, were tested for biochemical reactions and those conforming to salmonellae were typed serologically. Shigellae were classified according to their group antigen. A maximum of 6 colonies per specimen could thus be examined.

Using the disk method, the organisms were tested for sensitivity to the following antibiotics: ampicillin (25 μg.), cloxacillin (5 μg.), streptomycin (100 μg.), tetracycline hydrochloride (50 μg.), chloramphenicol (25 μg.), erythromycin (50 μg.), colistin (10 μg.), novobiocin (50 μg.), kanamycin (50 μg.), nitrofurantoin (100 μg.). A zone of inhibition of less than 2 mm. from the edge of the disk was taken to indicate a resistant organism. An Oxford strain of *Staphylococcus aureus* was used routinely as a control.

For parasitological investigation, the stools were examined by the merthiolate–iodine–formaldehyde (MIF) method (Sapero & Lawless, 1953).

On each occasion the schools were visited, water samples were taken from taps in the school grounds, placed in an insulated ice box and taken to the laboratory for bacterial counts and investigated for faecal *Escherichia coli*, using the methods recommended by the South African Bureau of Standards (1951). It was assumed that, since each house drew its water from the municipal water supply, this analysis would be representative of the general condition of the water.

Table 1. *Salmonella and shigella infections by age and sex*

Age (years)	No. of individuals	No. of specimens	Specimens infected with: Salmonellae No.	Specimens infected with: Salmonellae %	Specimens infected with: Shigellae No.	Specimens infected with: Shigellae %	Individuals infected with: Salmonellae No.	Individuals infected with: Salmonellae %	Individuals infected with: Shigellae No.	Individuals infected with: Shigellae %	All infected individuals No.	All infected individuals %
7–10	56	372	22	5·9	2	0·5	19	33·9	2	3·6	20	35·7
11–18	74	493	19	3·9	6	0·4	15	20·2	6	8·1	21	28·4
Total	130	865	41	4·7	8	0·5	34	26·2	8	6·2	41	31·5
Females	64	439	24	5·5	2	0·5	21	32·8	2	3·1	22	34·4
Males	66	426	17	4·0	6	1·4	13	19·7	6	9·1	19	28·8

Table 2. *Seasonal distribution of salmonella and shigella infections in 55 children*

Month of examination	*S. labadi*	*S. typhimurium*	*S. london*	*S. abortus bovis*	*S. derby*	*S. johannesburg*	*S. cerro*	*S. pomona*	*S. adelaide*	Percentage salmonella-infected individuals*	*Sh. flexneri*	*Sh. flexneri newcastle*	Percentage shigella-infected individuals	Total infected individuals No.	Total infected individuals %
Feb.	2	1	2	1	2	—	—	—	—	14·5	—	—	—	8	14·5
Mar.	1	2	1	—	1	—	1	—	1	12·7	—	—	—	7	12·7
May	1	1	—	—	—	—	—	1	—	5·5	1	—	1·8	4	7·3
June	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aug.	—	—	—	—	—	1	—	—	—	1·8	—	—	—	1	1·8
Sept.	—	2	—	—	1	—	—	—	—	5·5	—	—	—	3	5·5
Oct.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Jan.	—	2	1	—	—	1	—	—	—	7·3	—	4	7·3	8	14·5
Total	4	8	4	1	4	2	1	1	1	—	1	4	—	—	—

* Because of salmonellae being isolated from the same children on different occasions, twenty individuals over the year had twenty-six infections (see text).

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RESULTS

With an even distribution of males and females, the 130 children in the group selected passed 865 specimens of which 41 (4·7 %) yielded a growth of salmonellae and 8 (0·5 %) of shigellae (Table 1). Over the year of the investigation 41 (31·5 %) children had either salmonellosis or shigellosis. Of these, 34 (26·2 %) had a salmonella and 8 (6·2 %) a shigella infection. One child produced a salmonella in one specimen and a shigella in another. There were slightly more infections among females and the younger age group.

Because some were absent on the day of collection and others had left the school only 55 children were present for all eight investigations. The data of these are presented in Table 2. A total of 26 strains of salmonellae was isolated from 20 (36·4%) of these children and 5 shigellae from 5 (9·1 %) of them. From one child *S. typhimurium* was isolated three times, in March on the first occasion and January on the last. This was the only child from whom the same organism was isolated over a long period. Two others had the same salmonella in successive specimens, and another two children had different salmonellae in different specimens. The highest yield of salmonellae occurred in February and March (late summer), being 14·5 and 12·7 % respectively; there were no pathogens isolated in June (winter) or October (spring). From Table 3 it can be seen that only 5 (0·6 %) stools showed evidence of diarrhoea and these came from the group in which no pathogens were recovered. The consistency of the stools was thus unrelated to the presence or absence of pathogens. On the other hand, a temperature of 100° F. or higher was found in over 12 % of those who were infected with salmonellae or shigellae, but in less than 6 % of those from whom no pathogens were recovered. However, temperatures below 99·9° F. were no guarantee of absence of infection. Thus, from the consistency of the faeces and the temperature observations, it appears that most of the children from whom salmonella and shigella organisms were isolated were in apparent good health.

During the year *S. labadi* and *S. typhimurium* were most frequently isolated, with the group B–E constituting 75 % of the total isolations. On no occasion was *S. typhi*, *S. paratyphi A*, *B* or *C* found.

Of the 120 strains of salmonellae and shigellae tested against a range of antibiotics (Table 4) all were sensitive to streptomycin (100 μg./disk), tetracycline (50 μg./disk) and nitrofurantoin (100 μg./disk). A few strains were resistant to chloramphenicol, colistin and kanamycin. About a quarter of the strains were resistant to ampicillin and almost all to cloxacillin and novobiocin.

The results of bacteriological analysis of water samples taken at the schools (Table 5) show that the water was of good quality, and generally fulfilled the standards laid down by the South African Bureau of Standards (1951) for large towns. The three occasions (March, August, October) when counts of over 100 organisms/ml. were noted were probably due to constructional work which is prevalent in the township. On no occasion were any presumptive coliforms or faecal *E. coli* isolated.

During the period of the investigation, 64 of the 130 children (49·3 %) showed

Table 3. *Clinical observations related to infection*

		Consistency of faeces					
		Hard		Soft		Liquid	
	No. of specimens	No.	%	No.	%	No.	%
Pathogens not recovered	816	487	59·7	324	39·7	5	0·6
Salmonella infected	41	23	56·1	18	43·9	—	—
Shigella infected	8	6	75·0	2	25·0	—	—
Total infected	49	29	59·2	20	40·8	—	—

		Temperature (° F)					
		< 98·4		98·4–99·8		100 +	
		No.	%	No.	%	No.	%
Pathogens not recovered	816	406	49·8	363	44·5	47	5·7
Salmonella infected	41	19	46·3	17	41·5	5	12·2
Shigella infected	8	—	—	7	87·5	1	12·5
Total infected	49	19	38·8	24	49·0	6	12·2

Table 4. In vitro *resistance to antibiotics of isolated strains*

		Percentage of strains resistant to									
Genus	No. of strains	Ampicillin	Cloxacillin	Streptomycin	Tetracycline HCl	Chloramphenicol	Erythromycin	Coliston	Novobiocin	Kanamycin	Nitrofurantoin
Salmonella	91	24·1	98·9	0	0	6·6	47·3	4·4	96·7	1·1	0
Shigella	29	24·1	100·0	0	0	0	6·9	6·9	93·1	0	0

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the presence of parasites (Table 6). Flagellates were observed but were not reported, while *Entamoeba coli* was found in 73·0 % of the children. In addition, 13 children showed multiple parasitic infections. Stool consistency appeared to have no relationship with parasitic infections.

Table 5. *Water testing*

Months ...	Feb.	Mar.	May	June	Aug.	Sept.	Oct.	Jan.
Sholom Manne, no. of colonies/ml.	60	149	3	38	47	0	155	62
Sizaneni, no. of colonies/ml.	53	23	5	40	225	1	27	7

On no occasion were there any presumptive or faecal *E. coli*.

Table 6. *Incidence of faecal parasites in* 130 *Dube children*

	Individuals infected		Children with double infestation		
Parasite	No.	%	Parasite	No.	%
Hymenolepis nana	14	10·8	*Hymanolepis nana* + *Giardia*	3	2·3
Ascaris lumbricoides	31	23·8	*H. nana* + *Ascaris lumbricoides*	3	2·3
Enterobius vermicularis	2*	1·5	*A. lumbricoides* + *Giardia*	2	1·5
Giardia	15	11·5	*A. lumbricoides* + *Necator americanus*	1	0·8
Trichuris trichiura	4	3·1	*A. lumbricoides* + *Enterobius vermicularis*	1	0·8
Necator americanus	8	6·2	*Necator americanus* + *Trichuris trichiura*	3	2·3
Taenia	5	3·8			

* See text for explanation of low figure.

DISCUSSION

The main cause of human salmonellosis as a public health problem is attributable to foods of animal origin, egg products, human carriers, food handlers and contaminated water (Sickenga, 1964; Bowmer, 1964; American Public Health Association, 1963). Shigellosis, on the other hand, usually occurs under conditions where there is inadequate sanitation with the resulting abundance of flies and poor personal hygiene. Occasionally water may be incriminated (Wilson & Miles, 1964). Thus, persons living under low socio-economic conditions would be more prone to infections by both these groups of organisms.

The three surveys, Rustenburg, Witkoppen and the present one, Dube, were chosen to represent, in that order, increasing earning capacities of the families, with the resulting improvements in housing, clinic and hospital facilities, food and water supply. It was expected that the improved conditions of urbanization of the Bantu would result in noticeable decrease in the number of salmonellae and shigellae isolated. However, this was not the case (Table 7) since over the period of the survey 26·2 % of the children had salmonella infections and 6·2 % shigella infections. It is apparent that there is no clear-cut differentiation between the three socio-economic groups as far as the prevalence of these organisms is concerned. It is possible that the Dube children, although in the higher category, still lack some undefined essential nutritional factors, as well as basic education relating to personal hygienic habits.

Table 7. *Salmonellosis and shigellosis among Bantu children of different socio-economic standards in three comparable surveys*

	Rustenburg	Witkoppen	Dube
Socio-economic standard	Very poor	Poor	Better but inadequate
Water supply	Highly unsatisfactory	Unsatisfactory	Satisfactory
% salmonella-infected individuals	35·5	28·9	26·2
% shigella-infected individuals	25·0	4·7	6·2

In the group of fifty-five children who were present at each collection, just under half had an infection of either of the two pathogens at some time during the year. While in agreement with the Witkoppen finding, this is 25 % less than the Rustenburg figure. As found in other studies (Bokkenheuser & Greenberg, 1959; Richardson & Koornhof, 1965) there were more isolations in the summer months than in winter but on no occasion were there signs of outbreaks.

Clinical observations on the children indicated the mildness of the infections. None of the children from whom salmonellae and shigellae were isolated had watery diarrhoeal stools. The small group with oral temperatures over 100° F. yielded twice as many pathogens as the control group.

Taking into consideration the amounts of the antibiotics in the disks, which may vary in different laboratories, the antibiotic sensitivity findings were as expected. The relatively large amounts of streptomycin (100 μg.), tetracycline (50 μg.) and erythromycin (50 μg.) per disk may account for the higher percentage of strains sensitive to these drugs as compared with the findings of some authors (Wilson & Miles, 1964; Cruickshank, 1965).

The investigations of Ramsey & Edwards (1961) show that over the years from 1948 to 1960 there was a gradual increase from 0 to 29·0 % in the resistance of *S. typhimurium* to tetracycline. Manten, Kampelmacher & Guinée (1964) found a similar increase of from 2·1 % in 1959 to 24·4 % in 1962. This increase is attributed to the extensive use of tetracycline in these areas. It is interesting that our findings show that all the *S. typhimurium* strains were sensitive to tetracycline, probably because this drug is not used as frequently as in the above population groups.

Rustenberg and Witkoppen surveys showed that the water used in the homes was of inferior quality. It was suggested that this water was a factor in the transmission of salmonellosis and shigellosis. Furthermore, in a survey conducted in winter and summer at a school at Komatipoort in the Eastern Transvaal Lowveld (Richardson & Koornhof, 1965) it was shown that, of eight children from whom pathogens were isolated, six came from an area where water was drawn from a river from which numerous salmonellae were isolated. It was therefore interesting to find the same prevalence of salmonellae and shigellae in the present study, carried out in an area with excellent municipal water supply. Although it is reasonable to assume that water contamination plays some part in the transmission of these organisms it does not appear to be the most important factor in these surveys.

All the parasites implicated in this investigation (see Table 6), except taenia, are transmitted from person to person or by self-infection. Supplementing the bacteriological findings, this suggests a lack of personal hygiene. The low incidence of *Enterobius vermicularis* can be explained by the method used for examining the stools, as the ova are seldom found in them (Belding, 1958). One would expect a higher incidence, since the Bantu on urbanization are exposed more and more to the type of indoor micro-environment necessary for the maintenance of the enterobic life cycle.

An investigation carried out in 1962 (H. J. Heinz, personal communication) showed that a considerable amount of meat was available in the township from areas outside the control of the Municipal abattoirs. This was sold at lower prices than in the controlled shops and has a ready market because of the low salaries earned by the majority of the families. From a parasitological point of view this meat was inferior and explains the taenia infestations in children who have probably never left the area. Meat being a possible source of salmonella infections in these children, an investigation into the extent of salmonella infections in abattoirs, butchers' shops and uncontrolled sources, similar to that conducted by a Working Party of the Public Health Laboratory Service (1964), would provide valuable information.

From this study and its comparison with the previous surveys, it is apparent that there is a need for more efficient food control and for the education of the Bantu as to the importance of personal hygienic habits. Furthermore, as the socio-economic position of the Bantu improves, more judicious spending of money on food of higher nutritional value may have a bearing on their susceptibility to diarrhoeal diseases (Report, 1965).

SUMMARY

1. Faeces from apparently healthy Bantu children from schools in Soweto township near Johannesburg were examined eight times at fairly regular intervals over a period of 1 year.

2. Only fifty-five children were present for all eight investigations and, of these, 36·4 % yielded salmonellae and 9·1 % shigellae. Taking the group as a whole, 26·2 % of the children had salmonella infections and 6·2 % shigella infections.

3. Parasites were shown to be present in sixty-four of the 130 children during the period of the investigation.

4. As in other surveys, there were more isolations in summer than in winter.

5. *S. labadi* and *S. typhimurium* were most frequently isolated, with the group B–E constituting 75 % of the total isolations. *S. typhi*, *S. paratyphi A*, *B* and *C* were not found.

6. Water supplied to each house by the Johannesburg municipality was of good quality, yet it did not affect the incidence of salmonellosis and shigellosis.

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7. In spite of better socio-economic conditions the incidence of salmonellosis is comparable to the two previously mentioned surveys. These findings indicate a lack of instruction on personal hygiene and the importance of public health measures.

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REFERENCES

AMERICAN PUBLIC HEALTH ASSOCIATION. Conference of Public Health Veterinarians (1963). Epidemiology of Salmonellosis. *Publ. Hlth Rep., Wash.*, **78**, 1065.

BELDING, D. L. (1958). *Basic Clinical Parasitology*. New York: Appleton-Century.

BOKKENHEUSER, V. & GREENBERG, M. (1959). A review of Salmonellosis in South Africa. *S. Afr. med. J.* **33**, 702.

BOKKENHEUSER, V. & RICHARDSON, N. J. (1960). Salmonellae and shigellae in a group of rural South African Bantu school children. *J. Hyg., Camb.*, **58**, 109.

BOWMER, E. J. (1964). The challenge of Salmonellosis: major public health problem. *Am. J. med. Sci.* **247**, 467.

CRUICKSHANK, R. (1965). *Medical Microbiology*, 11th ed. Edinburgh: Livingstone.

MANTEN, A., KAMPELMACHER, E. H. & GUINÉE, P. A. (1964). Frequency of resistance to tetracycline and chloramphenicol among salmonella strains isolated in the Netherlands in 1962. *Antonie van Leeuwenhoek*, **30**, 10.

PUBLIC HEALTH LABORATORY SERVICE (1964). Report of a Working Party. Salmonellae in abattoirs, butchers' shops and home-produced meat, and their relation to human infection. *J. Hyg., Camb.*, **62**, 283.

RAMSEY, C. H. & EDWARDS, P. R. (1961). Resistance of salmonellae isolated in 1959 and 1960 to tetracyclines and chloramphenicol. *Appl. Microbiol.* **9**, 389.

REPORT (1965). Nutrition and Infection. *Tech. Rep. Ser. Wld Hlth Org.* no. 314.

RICHARDSON, N. J. & BOKKENHEUSER, V. (1963). Salmonellae and shigellae in a group of periurban South African Bantu school children. *J. Hyg., Camb.*, **61**, 257.

RICHARDSON, N. J. & KOORNHOF, H. J. (1965). Salmonellae and shigellae in a group of Bantu school children in the Eastern Transvaal Lowveld. *S. Afr. med. J.* **39**, 367.

SAPERO, J. J. & LAWLESS, D. K. (1953). The 'MIF' stain-preservation technic for the identification of intestinal protozoa. *Am. J. trop. Med. Hyg.* **2**, 613.

SICKENGA, F. N. (1964). Transmission of salmonellae and pathogenesis of salmonellosis in man. In *The World Problem of Salmonellosis*. Ed. E. van Oye. The Hague: Junk.

SOUTH AFRICAN BUREAU OF STANDARDS (1951). *Specification for Water for Domestic Supplies*. Pretoria: Council of the South African Bureau of Standards.

WILSON, G. S. & MILES, A. A. (1964). *Topley and Wilson's Principles of Bacteriology and Immunity*, 5th ed. London: Edward Arnold.