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Impact of water supply on the incidence of diarrhoea and shigellosis among children in rural communities in Madurai

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One thousand ninety one children, under 5 years of age, living in 5 villages with wells and protected water supplied through street taps and taps within houses, were observed twice a week for a year for diarrhoea and diarrhoic stools were examined for shigella. Incidence of diarrhoea was 21.51 (in villages with well), 36.78 (in those using street tap) and 23.52 (in those using taps within houses) respectively, the corresponding figures for shigellosis being 9.76, 12.52 and 4.72. In order to derive the full benefit of protected water supply, personal hygiene appears as important as ready availability of adequate quantities of water.

Gastrointestinal diseases constitute a major public health problem in India, particularly among infants and pre-school children. The State Governments have been investing large funds under the National Water Supply and Sanitation Scheme for the provision of protected water supply in rural and urban areas. Wells dug, driven, or drilled, as also water from reservoirs treated or untreated, with or without arrangement for overhead tank, piped or otherwise, constitute the usual source. Piped water supply is distributed through street faucets or house connections. The quantity is restricted to meet mainly the drinking water needs of the community.

Studies conducted in several countries¹⁻⁴ have indicated that the effectiveness of the protected water supply in controlling water-borne diseases in a community depends on (a) purity and wholesomeness, (b) quantity supplied, (c) whether the water is supplied within or outside the dwellings, and (d) whether the supply is continuous or not. The present investigation was undertaken to find out how far the public water supplies have controlled water-borne diseases in rural areas using the incidence of diarrhoea (shigellosis) as an index in children under 5 years of age.

Material and Methods

The study was conducted in five villages in Athoor block, Madurai district Tamil Nadu. The villages had one of the following sources of drinking water : (a) open

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dug wells with bucket and rope, and (b) treated water from a reservoir, delivered through taps on streets or within household to be referred to hereinafter as ST and TWH. The villages were similar in the socio-economic condition of the inhabitants, big enough to provide about 300 children under 5, and sufficiently near (10 km.) the Gandhigram Institute of Rural Health and Family Planning, to facilitate quick examination of the specimens.

Information on beliefs, customs, habits and knowledge of and attitude to different practices at home and in the village was collected in a structured schedule-cum-observation sheet from all households; the respondents were the mothers.

One thousand one hundred thirty children under 5 years of age in 691 households were studied (Table I).

TABLE I. SAMPLE SIZE OF CHILDREN BY WATER SOURCE.

Name of the village	Source of drinking water	No. of households enrolled	No. of children below 5, enrolled at the beginning of the study
1. Munnalakottai	Well	77	153
2. Kottaipatti	"	35	65
3. Kalikkampatti	"	103	170
4. Chinnalapatti	(a) Street tap	242	383
5. Sithayankottai	(b) Taps within households	146	203
	Taps within households	88	156
Total		691	1130

Eighty five children left the area and 4 died. The cause of death in these 4 was found to be fever of unknown origin while one had, in addition, mild diarrhoea. The remaining 1041 children were followed throughout the year. The age distribution at the beginning of the study, and children months observed under specific age groups are shown in Table II.

All the children were visited at home, twice a week, from January to December 1972, to detect the occurrence of diarrhoea. Diarrhoeal specimens were collected in sterile 1" wide-mouthed test-tubes containing 10 ml. of 30 per cent glycerol buffer saline, and transported immediately to the Institute laboratory. The specimens from the transporting fluid were inoculated directly on desoxycholate citrate agar (DCA), MacConkey agar (MA) and then twirled in selenite F. enrichment broth (SF) as advocated by Bhat and Myers⁵ and Bhat⁶. Following the overnight incubation at 37°C, subcultures

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TABLE II. NUMBER OF INFANTS AND CHILDREN AND NUMBER OF CHILDREN MONTHS UNDER OBSERVATION.

Age	No. of infants and children at the beginning of the period	Total children months of observations (From January to December, 1972)
0- 5 months	278	1403
6-11 "	57	1784
1- 2 years	204	2581
2- 3 "	203	2446
3- 4 "	189	2521
4- 5 "	199	2361
Total	1130	13102

were made from SF to DCA. Plates were incubated at 37°C. Typical, well isolated, individual non-lactose fermenting (NLF) colonies were marked at the bottom of the petri-dish, numbered, picked up, and further characterised using (a) triple-sugar iron agar (TSI), (b) mannitol motility medium (MM), and (c) peptone water (PW) for indol production. Non-lactose fermenting colonies, suggestive of shigella, were confirmed serologically. A little over 40 per cent of the shigella cultures isolated were selected at random and confirmed by the Reference Laboratory at the K.G. Medical College, Lucknow.

Stool specimens of 983 children were examined once for the presence of protozoa and helminths. One gram of stool was collected in screw-capped sterile glass bottles and transported immediately to the laboratory. They were subjected to direct microscopic examination and brine floatation method⁷.

Water samples were collected by the NEERI procedures⁸ regularly in 250 ml. sterile glass stoppered bottles for bacteriological examination, once-a-month from the sources (all wells, 10 out of 215 street taps, and 8 out of 234 taps within households) and twice-a-month from the domestic storage points (10 per cent of the total sample households) as indicated in Table III.

A total of 166 samples were examined every month for 11 months from February to December, 1972. They were examined for coliform organisms by the multi-tube dilution techniques⁹.

In addition, water samples from 8 wells and 2 overhead tanks were also subjected once to chemical examination for total acidity, total alkalinity, pH, total hardness, calcium hardness, magnesium hardness, chloride, total iron, nitrate nitrogen, ammonia nitrogen, and albuminoid nitrogen. All were found within permissible limits.

Water supply vis-a-vis diarrhoeal incidence

TABLE III. NUMBER OF WATER SAMPLES COLLECTED IN A MONTH (FROM BOTH SOURCE AND STORAGE POINTS).

Types of water source	Number of samples to be collected for bacteriological examination	
	Source (Once-a-month)	Storage point (Twice-a-point)
Wells	8	22
Street tap (ST)	10	24
Taps with households (TWH)	8	24
Total	26	70

Results

There were 299 cases of diarrhoea. The annual incidence (per 100 person years) of diarrhoea worked out in children depending upon well at 21.51, ST at 36.78, and on TWH at 23.52 (Table IV). While the difference in the incidence in diarrhoea for children depending on well and ST as also between ST and TWH ($P=0.01$) was significant (at 1 per cent level), no significant difference was found between well group and TWH group ($P>0.1$).

TABLE IV. INCIDENCE OF DIARRHOEA BY AGE AND SOURCE (PER 100 PERSONS/CHILDREN YEAR).

Age	Well	ST	TWH	Total
0-5 months	34.71 (14)	53.76 (25)	36.57 (11)	42.76 (50)
6-11 "	19.59 (11)	36.67 (18)	18.42 (8)	24.89 (37)
1-2 years	42.99 (34)	59.99 (39)	43.71 (31)	48.35 (104)
2-3 "	19.36 (14)	53.39 (38)	26.52 (16)	33.36 (68)
3-4 "	9.76 (7)	19.80 (15)	15.98 (10)	15.23 (32)
4-5 "	1.76 (1)	4.43 (3)	5.50 (4)	4.50 (8)
Total	21.51 (81)	36.78 (138)	23.52 (80)	27.38 (299)

Figures in parentheses indicate the actual number of diarrhoeal cases.

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The incidence of diarrhoea differed significantly ($P=0.001$) between age groups. Highest incidence was found in children of 1-2 years of age. No sex difference in the incidence was found (at 0.05 probability level). No seasonal variation was observed though the incidence seemed to follow, for a time, the curve of precipitation.

Average number of diarrhoeal attacks among children who had at least one attack was 1.5 in the well group and about 1.3 in the ST and TWH groups. The maximum number of episodes in children of any group was 4.

The shigella group of organisms was isolated from 96 diarrhoeal specimens out of 299 (32.11 per cent). The annual incidence (100 person years) of shigella infection was found to be significantly different in the three groups even at $P=0.001$ level: 8.76 (well), 12.52 (ST) and 4.72 (TWH), and for the whole group it was 8.79 (Table V).

TABLE V. INCIDENCE OF SHIGELLOSIS BY AGE AND SOURCE PER 100 PERSONS/YEAR.

Age	Total person years studied	Total	Well	Street tap	Taps within household
0-5 months	116.92	5.13 (6)	2.48 (1)	4.30 (2)	9.97 (3)
6-11 "	148.67	11.43 (17)	5.34 (3)	22.41 (11)	6.91 (3)
1-2 years	215.08	19.06 (41)	25.29 (20)	21.51 (14)	9.87 (7)
2-3 "	203.83	12.76 (26)	11.06 (8)	22.48 (16)	3.32 (2)
3-5 "	407.33	2.86 (6)	1.39 (1)	5.28 (4)	1.60 (1)

Number in parentheses indicate the actual number.

The percentage of shigella positive cases among the diarrhoeal children depending upon well, ST and TWH were 40.74, 34.07, and 20.0 respectively. Shigella was isolated among well water group almost twice as often as in the TWH group.

Isolation of shigella organisms was consistently high during the last three months of the year (prevailing monsoon), particularly in December when shigella organisms were isolated in 94 per cent of diarrhoeal stools.

S. flexneri was the most frequently encountered organism (88.6 per cent) followed by *S. boydii* (7.3 per cent), *S. dysenteriae* (3.1 per cent), and *S. sonnei* (1.0 per cent) (Table VI). *Shigella flexneri* 1b was the most frequently isolated serotype, followed by 4, 2, 5, 6, 3 and 1a: *Shigella boydii* serotypes 3, 11, and 12 were encountered. *Shigella dysenteriae* 3 was isolated in 3 cases.

Other organisms isolated from diarrhoeal stools in which shigella organisms were not found were *Alkalescens dispar* and Providence group on 3 and 25 occasions

Water supply vis-a-vis diarrhoeal incidence

TABLE VI. ISOLATION OF SHIGELLA SUBGROUPS FROM CASES BY SOURCES OF WATER.

Shigella subgroup	Well group		ST group		TWH group		Total	
	No.	%	No.	%	No.	%	No.	%
<i>S. flexneri</i>	30	31.3	42	43	13	13.6	85	88.6
<i>S. boydii</i>	2	2.1	3	3	2	2.1	7	7.3
<i>S. dysenteriae</i>	1	1.0	2	2.1	—	—	3	3.1
<i>S. sonnei</i>	—	—	—	—	1	1.0	1	1.0
Total	33	34.4	47	48.1	16	16.7	96	100.0

respectively. No effort was made to isolate *E. coli*, Salmonella and other members of the Enterobacteriaceae family.

Seventy two per cent of the samples collected from ST and 78 per cent from TWH did not conform to the standards for treated water (Table VII) IMVIC+44°C for detecting the presence of *E. coli* I, introduced during the last 4 months (September to December) indicated the presence of *E. coli* I. Nine times in 40 samples of ST, 6 in 32 TWH and 25 in 32 well water samples.

TABLE VII. MPN INDEX OF COLIFORMS ESTIMATED AT THE SOURCE AND DOMESTIC STORAGE POINTS. (EXPRESSED AS PERCENTAGE OF THE TOTAL NUMBER OF SAMPLES TESTED).

Particulars	MPN index of coliforms		
	0	10 and below	11 and up to 1800
A. At the source			
Well (88)	—	2.27 (2)	97.73% (86)
ST (110)	28.18% (31)	47.27% (52)	24.55% (27)
TWH(88)	21.59% (19)	62.50% (55)	15.91% (14)
B. At the domestic storage points			
Well (434)	—	—	100% (484)
ST (528)	—	14.20% (75)	85.80% (453)
TWH (528)	—	12.12% (64)	87.88% (464)

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Barring only 12 to 14 per cent, all other samples collected from domestic storage points were grossly polluted (as evidenced by higher MPN index of above 10). *E. coli* I was found in 34 per cent and 40 per cent of samples collected from the storage points of ST and TWH respectively (Table VII). From the households where there was a diarrhoeal attack, 97 per cent of the samples collected and examined from the domestic storage points showed MPN of coliform in excess of 10 (Table VIII).

TABLE VIII. MPN OF COLIFORMS ENUMERATED FROM THE WATER SAMPLES COLLECTED FROM THE HOUSEHOLDS WHERE THERE WAS A DIARRHOEAL ATTACK.

Particulars	Well	ST	TWH	Total
1. No. of water samples examined	28	66	25	122
2. MPN index				
1-10	—	3	1	4
Above 10 and upto 1800+	28	63	27	118

21.17 per cent of the children depending on well, 22.53 per cent on ST, and 32.4 per cent on TWH were free from cysts and ova. About 70 per cent of the children examined revealed the presence of one or the other of cysts, with not much difference among the three groups.

The proportion positive for *Entamoeba histolytica* cyst in the well group (51.7 per cent) was significantly different at 0.1 per cent level from ST and TWH group (32.4 and 32.8). The percentage positives detected for the ova of various helminths in well water, ST and TWH groups were 19.54, 12.96 and 13.08 respectively (Table IX).

Ancylostoma duodenale and *Hymenolepis nana* were the two dominating helminths accounting for 5.8 and 6.2 per cent. Source-wise, *Ancylostoma* affected most well group children (7.5 per cent), TWH the least (3.8 per cent), and ST group in the middle (6.2 per cent). This difference was significant at 1 per cent level.

Multiple infection index (average number of different parasites per infected person) worked out at 1.6 for well and 1.4 for ST and TWH.

Discussion

The incidence of diarrhoea among children under 5 years of age as reported in the study, may be considered to reflect a true situation in rural India since data were collected by the same interviewer who had been trained before, through twice a week visit to the homes, throughout the whole year. Studies in USA^{10,11}, Egypt¹² and Indonesia¹⁴ were either on a weekly, biweekly, or a monthly basis.

For the purpose of this project, diarrhoea was defined as a condition characterized by more than 3 passages a day of unformed stools, watery, semisolid, liquid or frothy, with or without blood or mucus, often and not necessarily accompanied by abdominal pain. In the Indonesian study, an infant was considered to be suffering from

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TABLE IX. INFECTION RATE (%) WITH INTESTINAL PARASITES BY SOURCE.

Groups	Protozoa cysts (in per cent)					Helminthic ova (in per cent)						
	<i>Entamoeba histolytica</i>	<i>E. coli</i>	<i>Giardia</i> sp	<i>E. histolytica</i> alone or in combination with others	Total infected	<i>Ascaris lumbricoides</i>	<i>Ancylostoma duodenale</i>	<i>Taenia</i> sp	<i>Enterobius verucularis</i>	<i>Hymenolepis nana</i>	<i>Ancylostoma duodenale</i> alone or in combination with others	Total
Well	18.5	7.2	10.8	51.7	72.6	Nil	7.5	0.3	1.0	6.2	11.6	19.54
ST	12.7	20.3	10.0	32.4	69.9	—	6.2	—	0.3	5.0	7.7	12.96
TWH	12.5	14.6	12.1	32.8	64.5	1.2	3.8	—	0.3	7.5	4.1	13.08
All type	14.5	14.3	11.0	38.6	69.0	0.4	5.8	0.1	0.5	6.2	7.7	15.05

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diarrhoea when more than 4 stools were produced in 24 hours; neither consistency nor colour was considered. Incidence of diarrhoea among users of well and of TWH shows a remarkable similarity in age groups. Maximum incidence in the 1-2 years of age may be associated with the infant weaning practices. This has been also observed by others¹³⁻¹⁵.

The higher percentage recovery of shigellae (32.11 per cent) is probably because most of the specimens were plated within 2 hours of passing after defecation. The differential incidence of shigella in the proportion of 2 : 3 : 1 among the children in well, ST and TWH groups is significant. Low recovery from neonates and also from 6 to 11 months children is in conformity with the findings of earlier workers¹⁶⁻¹⁹. The highest incidence during 1-2 years also in agreement with the experience, Indian and outside^{11,12,20}.

No difference in the incidence by sex was also observed by Hardy and Watt¹¹, though Cruickshank²¹ reported a higher incidence in male than in female children in England.

The dominant prevalence of *Shigella flexneri* (88.6 per cent) has also been reported in India^{22,23}, Egypt¹², Uganda²⁴, West Pakistan²⁵ and Guatemala²⁶. Age-wise difference in the prevalence of subgroups was not observed.

In general, protozoal infection was heavy and helminthic low. The ratio of infection by ingestion to penetration 1 : 15 is in sharp contrast with what was observed in Calcutta²⁷ and in Varanasi²⁸. Intestinal parasites did not appear to have any influence in causing diarrhoea. This was observed also in Indonesia and Costa Rica^{14,29}.

Water stored in homes is invariably found contaminated, irrespective of the source including even treated and chlorinated water. This situation also exists in other developing countries as shown by studies in Brazil³. The existence of latrines in the houses did not make any difference in the incidence among children in TWH group. How far inadequate washing of hands of mothers after toilet is responsible for this is not known. This aspect needs study, as reported recently by Sur³⁰. Presence of cattle shed did not appear to have any influence on the incidence of diarrhoea. The effect of fly was not studied.

It would thus appear that apart from the provision of protected water supply promotion of public education for adopting good sanitation practices including personal hygiene would be necessary, along with ensuring adequate and continuous water supply, to derive optimum benefits and to prevent water-borne infections.

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