Impact of drainage and sewerage on diarrhoea in poor urban areas in Salvador, Brazil

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Abstract

A longitudinal prospective study of the effect of drainage and sewerage systems on diarrhoea in children aged < 5 years was conducted in 9 poor urban areas of the city of Salvador (population 2.44 million) in north-east Brazil in 1989–90. Due to complex political and administrative reasons, 3 areas had benefited from drainage improvements, 3 from both drainage and sewerage improvements, and 3 from neither. An extensive questionnaire was applied to collect information on each child and on the conditions of the household, and mothers recorded diarrhoea episodes in their children aged < 5 years daily for 1 year, using calendars. Fortnightly home visits were made to collect the data. The incidence of diarrhoea in children in neighbourhoods with drainage was less than two-thirds, and in neighbourhoods with drainage and sewerage less than one-third, of the incidence in neighbourhoods with neither. After controlling for potential confounders, the proportion of children with 'frequent diarrhoea' showed the same significant trend across the study groups. Though the groups were not exactly comparable, more than one child was monitored per household, and it was not possible to rotate fieldworkers between study groups, the study provides evidence that community sanitation can have an impact on diarrhoeal disease, even without measures to promote hygiene behaviour.

Keywords: diarrhoea, incidence, children, risk factors, drainage, sanitation, Brazil

Introduction

There has been increasing concern in recent years that excreta disposal has been neglected in comparison with water supply in the developing world, and that as a result the extension of coverage with sanitation has lagged behind (WHO/UNICEF, 2000). Excreta disposal is one of the primary barriers to the transmission of faeco-oral infections, and it has been argued that sanitation has a greater impact on health than water supply (Bateman, 1991; Esrey *et al.*, 1991). Better evidence of the health benefits of sanitation is an essential requirement of the advocacy needed to improve this situation.

Unfortunately, most of the existing evidence comes from observational studies which compare households which have installed latrines with others which have not. They are therefore based on self-selected exposure groups and are thus beset by serious problems of confounding by socio-economic status (Cairncross, 1990) and hygiene awareness (Hoque *et al.*, 1995). As their unit of study is the individual household, they neglect the substantial externalities in terms of the additional health benefits which accrue when sanitation is improved for the community as a whole (Bateman & Smith, 1991). Most of the studies also relate to rural settings, whereas the health impacts of sanitation are likely to be greater in the urban areas in which half of the world's population now live (Esrey & Sommerfelt, 1991).

We report the results of a study of the health impact of environmental sanitation in poor urban areas in Salvador, Brazil, considering diarrhoeal disease as an indicator.

Methods and Study Population

Study site and intervention

The study was conducted in 1989–90 in the Camurujipe Valley, an area of Salvador in north-east Brazil with a number of informal low-income settlements. In the early 1980s, the Municipality of Salvador constructed low-cost surface water drainage systems (which are used also for sewage disposal) in 17 of 34 neighbourhoods. In the mid-1980s, they constructed simplified sewerage systems in 11 others. These measures were accompanied by paving of some streets and, in some areas, by improvements in the water distribution system and by giving the residents land tenure. By the time the project funds were fully spent, 6 neighbourhoods had still not been provided with either drainage or sewerage. It had been planned to cover all 34 with both services, but unfortunately this did not prove financially possible.

This pattern of sanitation development thus resulted in 3 groups of communities, those with sewerage and drainage, those with drainage only, and those without either. Communities were not allocated randomly to these groups but selected on politico-administrative criteria. The explicit criteria for selection of priority neighbourhoods for intervention were ease of access for construction, area occupied, current lack of basic services, level of community organization, type of housing, proportion of households with low and casual incomes, and physical characteristics such as vulnerability to flooding or landslides. No health criteria were utilized. In practice, however, political patronage and pressure from construction firms preferring to work in the easiest terrain also played a part.

Simplified sewerage systems were added to the intervention when the programme was already under way, so that the first 17 neighbourhoods selected did not benefit from them. We believe that, in practice, socio-economic status, environmental quality and health status played little part in the selection of the communities to benefit from the programme; we investigated and controlled for differences in group characteristics in the assessment of health impact.

The drainage system installed in this area was characterized by a system of rainwater drainage channels made from prefabricated components of reinforced concrete. They are covered and also serve as footpaths or stairways (Fig. 1). Lateral openings allow for the entry of surface water and sewage connections from nearby houses. They are connected to large, lined interceptor drainage channels which discharge into the Camurujipe River. The simplified sewerage system, where installed, involved 100 mm diameter plastic pipes laid at a shallow depth along either side of the channel, discharging into the same interceptors. House connections were the same size, with simplified junction boxes and usually a grit and grease trap.

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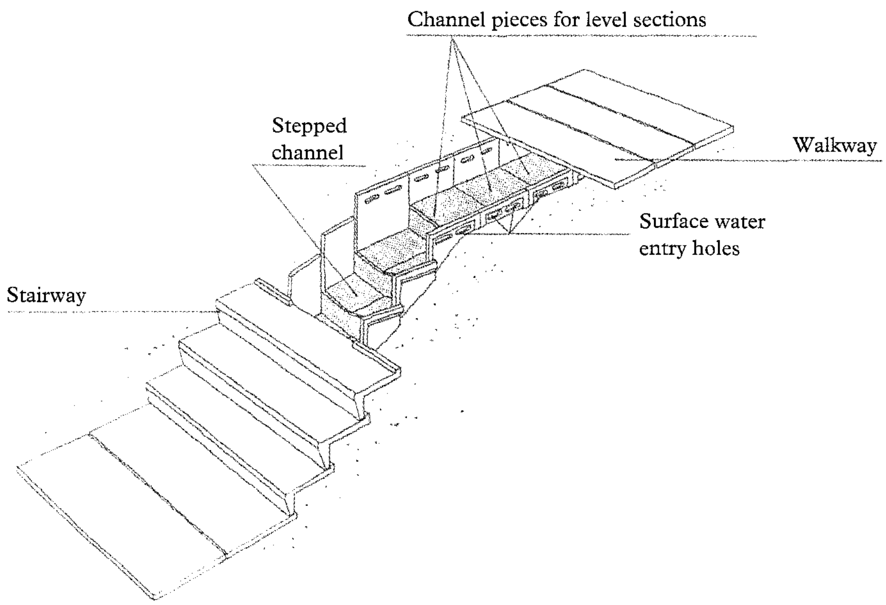

Fig. 1. Design of drainage channels and stairways used in study groups 2 and 3, Salvador, Brazil, 1989–90.

Selection of study population, and consultation

Three groups of 3 neighbourhoods, 9 in all, were chosen from the full list of 34 by stratified random sampling, according to the environmental infrastructure available: group 3 consisted of 3 neighbourhoods which had both drainage and simplified sewerage systems throughout; group 2 consisted of 3 with drainage systems used for both purposes; and group 1 (the control) consisted of 3 with no intervention.

In each selected neighbourhood, about 120 households were randomly selected, with the objective of recruiting a nominal 130 children aged < 5 years from each community. Further details are given in Moraes (1996).

Public meetings were held in each neighbourhood to explain the nature and purpose of the research and to seek the residents' collective consent. A total of 66 such meetings were held before and during the study.

Social and environmental data collection

A pre-coded questionnaire was administered at the beginning of the fieldwork to each selected household to collect information on socio-economic, demographic, cultural, environmental and health aspects.

The questionnaire included information on the family members, breastfeeding, weaning practices, diarrhoea episodes in children aged < 5 years, environmental and household sanitation, and socio-economic status. Housing characteristics included the number of rooms, area, floor, walls, roof, electricity, and water supply, storage and usage. The questionnaire also included excreta and sullage disposal and solid waste disposal facilities; all sites within 10 m of the house door with visible sewage on the ground, sewage overflowing from stairways, or rubbish were observed and counted; any reported increase of vectors during the last year (rats, cockroaches and flies) was noted; income, religion and ownership of goods (a radio, a refrigerator, a television and the house plot) were also recorded.

The questionnaire was administered by the 9 trained female fieldworkers, who were residents of the neighbourhoods they covered, as it was dangerous for outsiders to walk about at all hours. The compliance of the respondents was over 98%.

Diarrhoeal morbidity

A 2-week 'calendar' designed for use by illiterate adults, and bearing a photograph of each child aged < 5 years, was used to avoid recall bias while keeping to only one home visit per week. Mothers were encouraged to record diarrhoea episodes on these. In this study 'diarrhoea' was defined for all children aged < 5 years as looser than usual stool consistency and increased frequency, as noted by their mothers or guardians. The fieldworker also interviewed the mothers every 2 weeks about each episode of diarrhoea in their children; an episode was defined as 1 or more days of diarrhoea separated from any other episode by at least 2 diarrhoea symptom-free days (Morris *et al.*, 1994).

This information was collected over a period of 1 year. During this period, all children who reached the age of 60 months or moved away were dropped from the study and all children born in the study households were enrolled.

Quality control measures

Each questionnaire and each completed form or diarrhoea calendar from the field was reviewed by the field supervisor and the quality control officer. A subsample of 10% of these were then reviewed by the principal investigator. Only 3% of the questionnaires were returned to the field to correct and complete. During the diarrhoea monitoring, unannounced household visits were carried out by the field supervisors and by the principal investigator to check that the calendars were being duly completed. Each household was visited at least twice per fortnight.

Data handling and analysis

Additional quality control checks were performed before and after data entry. The analyses of the data were conducted using SPSS/PC+ 4.0.1. (SPSS Inc., Chicago, IL, USA).

Incidence rates, expressed as episodes per child per year, were computed from the ratio between the number of new episodes occurring and the number of child-fortnights of observation obtained from the calendars. Incidence rates were compared by calculating the incidence density ratio (IDR), which is the incidence rate experienced in one study group divided by the incidence rate in another. Test-based 95% CIs for the IDR (Kleinbaum *et al.*, 1982) were calculated, although these confidence limits should be interpreted with some caution because repeated episodes of diarrhoea in a child are not always independent events.

Logistic regression analysis was used to study the combined effects of several potential confounding factors and of study group. The analysis followed the approach used by Aziz *et al.* (1990), and the observed number of episodes that a child experienced in a year was compared to the expected number of episodes for a child of the same age group and followed-up over the same time period in the year, eliminating the age and seasonal effects in the calculations. Those children who had more than twice the expected number of episodes were classified as a 'frequent diarrhoea' group. The proportion of children classified as having 'frequent diarrhoea' was compared between the 3 study groups. The method used in the logistic regression was forced entry, by which all variables are entered in a single step (Norusis, 1990).

Results

Characteristics of the study population

At the beginning of the study 1162 children aged < 5 years were living in 732 of 1005 households surveyed in the 9 neighbourhoods. In addition, 113 children in the same households born during the 12-month follow-up diarrhoeal study were incorporated in to the study, resulting in 1275 children aged < 5 years studied in the period from November 1989 to November 1990.

The mean age of the children was 27.9 months at recruitment to the study, and 52.4% of them were male. In all 3 study groups there were slightly more children in the age group < 12 months than in the other 12-month intervals due to the continued recruitment of newborns. No significant differences were found between the study groups regarding the age and gender distributions of the children.

Characteristics of the three study groups

Table 1 compares the 3 study groups, separating the variables likely to have been affected by the environmental improvements from those which were independent of them. No significant differences between the 3 groups were observed in access to electricity, number of bedrooms, household size, religion, animals in house and type of water supply. A number of differences between households in the control group (no intervention) and the other study groups arose from the fact that the former were more recently established settlements. Half of the mothers in the control group originated from rural areas compared to a quarter in the drainage group and a third in the group which also had sewerage. Households in the intervention areas had a longer mean duration of residence (17.4 years) than in the control areas (11.2 years) ($P < 0.001$).

The mean level of schooling of the household heads in the control group was less than in the other study groups ($P < 0.001$). This was also true of the mothers, who also tended to be younger in the control group.

No significant differences were found between the study groups regarding the household heads' and mothers' occupations. Most of the heads worked as construction workers, security guards, lorry drivers or as manual labourers, while the mothers, if employed, were engaged as domestic workers or as casual workers in the local service industries.

There were significant differences between the 2 intervention groups and the control group, attributable to the intervention. Excreta and sullage disposal were better and more streets were paved in the intervention groups ($P < 0.001$), and this made an improved rubbish collection service possible. The number of sites within 10 m of the house door where sewage was visible on the ground or where rubbish had accumulated was highest in the control and lowest in the sewerage group ($P < 0.001$). The reliability of water supply distribution was also better in the intervention groups than in the control group ($P < 0.001$). Such differences were to be expected in view of the nature of the interventions.

To the extent that a factor may have predisposed some communities to receive the intervention, while itself being directly associated with better health status, it was a potential confounding factor. If, however, it was a consequence of the intervention, then any improvement in health status it bestowed could be considered to be a health benefit of the intervention itself. The 3 study groups, while being of low-income population, presented several differences in socio-economic, cultural and environmental aspects, and this had some implications when comparing them. The health impact assessment analysis took these differences into account.

Comparison between study groups

Table 2 shows that the overall incidence of diarrhoea in the control group was more than 3 times that in the sewerage group, with the 'drainage only' group in an intermediate position. There was also a significant difference in incidence rates between the 2 intervention groups; children living in neighbourhoods with a sewerage system experienced half as many episodes of diarrhoea as those living in neighbourhoods with only drainage. The prevalence—the mean percentage of days that children had diarrhoea—fell progressively from group to group in the same way, representing a significant difference when the groups were compared.

Persistent episodes (those lasting more than 14 d) accounted for only a very small proportion of all episodes in the 3 study groups, and less than 17% of diarrhoea days.

Controlling for confounding factors

As noted above, there were differences between the 3 groups, some of which could be associated with the risk of diarrhoeal disease. The factors that showed significant associations with diarrhoea and were not considered to be consequences of improved environmental sanitation were the child's age, gender and birth order, the number of children in the household aged < 5 years, crowding, mother's education, monthly per capita income, exclusive use of kitchen, animals in the house, presence of a washstand, water usage and house floor material. These factors were selected as potential confounding variables for inclusion in the multivariate logistic regression analysis, which was then used to control for their combined effects on the association between diarrhoea and environmental sanitation. Variables which were not significantly associated with diarrhoea (such as rural vs. urban origin) were not used in that analysis. The outcome variable used was 'frequent diarrhoea' (more than twice the expected number of episodes). Complete data for analysis were available for 961 children.

Table 3 shows the results in the form of unadjusted (crude) and adjusted odds ratios (ORs). The OR was roughly equivalent to the ratio between 2 study groups of the risks to children of having 'frequent diarrhoea', other things being equal. The study groups were compared with the least exposed group (the group with both drainage and sewerage), so that an OR greater than unity implied that the association with the risk factor was in the expected direction.

After adjustment for potential confounders, the estimated ORs were slightly lower than the crude values, but the association between diarrhoea incidence and environmental sanitation (excreta and sullage disposal) remained highly significant ($P < 0.0001$).

Age- and gender-specific impact

Age-specific diarrhoeal morbidity measures were calculated, and the overall incidence rates are shown in Fig. 2. The difference between age groups was most marked, and consistently in the expected direction, in children aged > 12 months but not so clear in infancy.

Table 1. Household characteristics in three study groups, Salvador, Brazil, August–September 1989

Variable	Level	Group 1 Control ($n = 322$)	Group 2 Drainage ($n = 345$)	Group 3 Sewerage ($n = 338$)	Significance[c] P G1 vs. G2	G2 vs. G3
Variables unaffected by improvements in drainage and sewerage systems						
Time of residence (years)[a]		11.2 (6.6)	17.4 (9.6)	17.4 (10.1)	**** <0.0001	NS 1.0
Mother's origin	Salvador	35.2%	46.3%	48.5%	**** <0.0001	NS 0.60
	Other urban	15.2%	25.9%	18.1%		
	Rural area	49.6%	27.8%	33.4%		
Religion	Catholic	80.1%	74.8%	73.7%	NS 0.12	NS 0.81
Schooling of household head (years)[a]		4.1 (3.0)	5.7 (3.5)	5.5 (3.5)	**** <0.0001	NS 0.45
Monthly per capita income[a,b]		0.4 (0.3)	0.6 (0.4)	0.7 (0.5)	**** <0.0001	** 0.002
No. of persons in household[a]		6.3 (2.7)	6.0 (2.5)	6.1 (2.9)	NS 0.14	NS 0.63
House floor area	< 16 m^2	26.1%	27.8%	8.3%	NS 0.68	**** <0.0001
House floor type	Earth	13.0%	3.5%	5.0%	**** <0.0001	NS 0.52
	Cement/other					
House walls type	Brick	83.9%	91.6%	90.5%	** 0.003	NS 0.72
	Mud/other					
No. of bedrooms[a]		1.8 (0.7)	1.9 (0.8)	1.9 (0.8)	NS 0.085	NS 1.0
Water supply	Piped	86.0%	88.4%	89.9%	NS 0.42	NS 0.60
Presence of washstand	No	80.1%	60.3%	63.6%	**** <0.0001	NS 0.41
Electricity	Yes	98.4%	98.3%	99.4%	NS 0.91	NS 0.29
Animals in house	Any	48.8%	50.1%	46.4%	NS 0.78	NS 0.37
Variables affected by improvements in drainage and sewerage systems						
Ownership of house plot	Owner	49.4%	75.4%	83.1%	**** <0.0001	** 0.016
Toilet type	Flush	73.3%	86.1%	89.9%	**** 0.00012	NS 0.096
	Pit latrine	3.4%	0.9%	1.2%		
	None	23.3%	13.0%	8.9%		
Excreta disposal	Ground or open drain	45.0%	3.2%	1.8%	**** <0.0001	NS 0.347
Sullage disposal	None	73.0%	11.3%	6.2%	**** <0.0001	* 0.027
Sewage visible near house (< 10 m)	Any	85.7%	47.5%	4.4%	**** <0.0001	**** <0.0001
Street	Unpaved	87.6%	6.7%	2.4%	**** <0.0001	* 0.012
Water supply distribution	Regular	38.0%	71.0%	69.5%	**** <0.0001	NS 0.858
No. of water taps	⩾ 3	20.2%	47.0%	54.1%	**** <0.0001	NS 0.092
	1–2	65.8%	41.4%	35.8%		
	0	14.0%	11.6%	10.1%		
Water consumption (litres/capita/d)[a]		48.3 (38.7)	67.1 (60.0)	78.1 (71.4)	**** <0.0001	* 0.023
Rubbish near house (< 10 m)	Any	58.1%	29.9%	11.2%	**** <0.0001	**** <0.0001

[a]Mean (SD).
[b]Monthly per capita income is given as a proportion of the Brazilian Minimum Wage (US$63 in August 1989).
[c]The two-sided normal test was used for all quantitative variables, and χ^2 (or Fisher's exact test) for all others: NS, not significant at 5% level; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; ****$P < 0.0005$.

The difference between study groups was similar for males and females.

Individual household sanitation

Most of the children (87.8%) were in households with flush toilets, though in the control group these discharged into the street. Most of the remainder (9.5%) had no excreta disposal facility, although 2.7% had pit latrines. Diarrhoea incidence among children in households with a flush toilet was 3.02 episodes/child/year, significantly less ($P < 0.001$) than the incidence (6.19 episodes/child/year) among those with with no facility at all. Among those with pit latrines, the incidence was 4.34 episodes/child/year.

Discussion

The primary objective of this study was to evaluate the impact of environmental sanitation on diarrhoeal

Table 2. Diarrhoeal morbidity of children aged < 5 years by study group, Salvador, Brazil, November 1989–November 1990

	Group 1 Control ($n = 432$)	Group 2 Drainage ($n = 426$)	Group 3 Sewerage ($n = 417$)
Child-days of observation	114 305	111 721	118 217
Diarrhoeal incidence[a]	5.55	3.32	1.73
Incidence density ratio[b]	–	0.60[c] (0.56–0.65)	0.31[c] (0.28–0.34)
Mean percentage of days with diarrhoea	4.9	3.5	1.9
Percentage of episodes lasting > 14 d	1.4	3.0	2.1

[a]Episodes/child/year.
[b]Incidence rate experienced divided by the incidence rate in group 1 (95% CI).
[c]χ^2 test for significance of difference from unity, $P < 0.0001$.

Table 3. Proportion of children with 'frequent diarrhoea' by study group, Salvador, Brazil, November 1989–November 1990

Environmental sanitation group	Frequent diarrhoea[a]	Odds ratio (95% CI)[b] Unadjusted	Adjusted[c]
No intervention	28.0	9.89 (5.81–16.83)	8.10 (4.99–13.16)
Drainage only	11.6	3.33 (2.15–5.15)	2.97 (2.00–4.41)
Sewerage and drainage	3.8	1.00 –	1.00 –

[a]Percentage of children with 'frequent diarrhoea' (more than twice the expected number of episodes).
[b]Odds Ratio (95% CI) by comparison with the least-exposed group (drainage and sewerage).
[c]Adjusted for child's age, gender and birth order, number of children aged < 5 years in the household, crowding, mother's education, monthly per capita income, exclusive use of kitchen, animals in the house, presence of a washstand, water usage and house floor material.

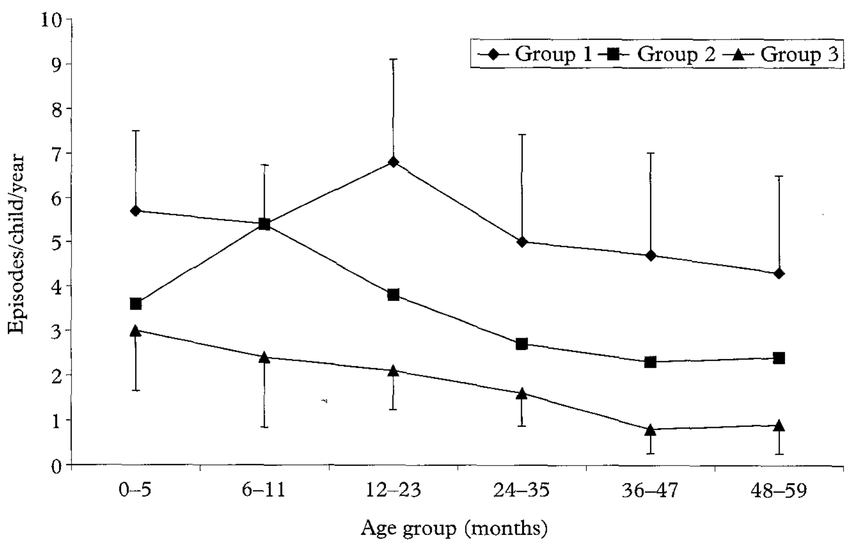

Fig. 2. Incidence of diarrhoea in children by age and study group, Salvador, Brazil, November 1989–November 1990. Key: Group 1, no intervention; Group 2, drainage only; Group 3, sewerage and drainage. For clarity, only the upper 95% CIs are shown for group 1 and the lower 95% CIs for group 3. The 95% CIs for group 2 were of intermediate range.

morbidity in young children. The incidence of diarrhoea was consistently lower in the groups with improved community sanitation throughout the study period, and lowest in the group with the fullest provision—sewerage and drainage systems. The sewerage and drainage systems still had a significant effect on diarrhoeal morbidity after controlling for confounding factors. The incidence of diarrhoea in the group with a sewerage and drainage system (group 3) was one-third, and in the group with a drainage system only (group 2) it was two-thirds, of that in the group lacking sanitation infrastructure (group 1).

The intervention groups enjoyed a slightly more reliable water supply service than the control group, but it is unlikely that the differences we describe were principally attributable to that, for 2 reasons. First, there was little difference in continuity of the water supply between the 2 intervention groups, but the group with a full sewerage system had substantially less diarrhoea. Second, we controlled for water usage as one of the potential confounding factors.

Children in the same household were not statistically independent. On average there were 1.74 children in the study per household. However, the differences between the study groups would still be significant if half of the children were dropped from the study to leave only one child per household, as can be seen from the confidence intervals in Tables 2 and 3. Repeated bouts of diarrhoea in a single child were also not independent, but that problem did not affect the analysis of the risk of 'frequent diarrhoea' (Table 3).

The difference in diarrhoea incidence between the study groups was unlikely to be due to observer bias. Although each fieldworker was a resident of her community and it was not possible to interchange observers or rotate them between communities, the consistency of their data was supported by the fact that the incidence of diarrhoea in the 3 individual communities within each environmental sanitation group was not significantly different. The study had some methodological limitations, including the absence of pre-intervention data and the small number of communities (3) in each group. We attempted to address this through the control of confounding variables in the data analysis. Furthermore, the magnitude of the effect observed and the 'dose–response' effect seen according to type of sanitation, lead us to conclude that improved environmental sanitation can have a positive impact on diarrhoeal morbidity in young children in poor peri-urban areas such as those studied.

This might not seem a new conclusion, as the health benefits of sanitation have been documented before (Esrey *et al.*, 1991). However, much of the existing evidence for the impact of sanitation on diarrhoeal disease is weak as it is based on self-selected exposure groups and is not safe from the possibility of confounding by socio-economic status, awareness of hygiene, or any other factor which predisposes individual households to install a family toilet (Cairncross, 1990; Cairncross & Kolsky 1997). Moreover, such studies neglect the amplification of impact which is likely to result when a whole community benefits from sanitation improvements, and the important degree to which diarrhoea is transmitted in the public environment, as compared with the household, when community sanitation infrastructure is lacking (Koopman, 1980). It is noteworthy that the crude ratio of diarrhoea incidence between households having a latrine and those without was 2, but that this increased to more than 3 (Table 2) when the comparison was made between whole communities with sanitation infrastructure (sewerage and drainage) and those with none.

The difference in the peak age of diarrhoea incidence between the sewerage and the control groups (Fig. 2) suggested that the component of diarrhoea transmission which was prevented by the environmental sanitation was largely among children aged > 1 year rather than among infants; this is not surprising, as children aged > 1 year are more likely to play in the street and be exposed to the faecal contamination of the environment in the public domain (Cairncross *et al.*, 1996) than infants.

Differences in the proportion of persistent episodes could be due to differential impact on persistent, relative to acute diarrhoea; but the number of persistent episodes in each study group was too small (< 40 in each group) to draw firm conclusions.

Contrary to what has been suggested in one recent study (Esrey, 1996) and in recent debates in Brazil about the national level of coverage with sanitation (Anonymous, 2000), the impact of sanitation in individual households was not significantly affected by the type of toilet; there was no significant difference in the incidence of diarrhoea between households with a cistern-flush toilet and a rudimentary pit latrine, though the number of households with pit latrines was too small to detect small differences.

The present study has demonstrated that community sanitation infrastructure can have a significant impact on diarrhoeal disease, even without any significant measures to promote hygiene behaviour changes within the household. Further study of the mechanisms underlying this impact would help to define the mixture of environmental infrastructure and health promotion interventions likely to produce the greatest health benefit.

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