

Water Supply, Sanitation and Diarrhoeal Disease in Nicaragua: Results from a Case-Control Study

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A case-control study of risk factors for child diarrhoeal disease was undertaken in a rural area of Nicaragua. Some 1229 children under the age of five were matched with an equal number of children of the same age presenting with other illnesses unrelated to water and sanitation. The main types of water supply were sampled at monthly intervals and tested for the presence of faecal coliforms in order to characterize their microbiological quality. In spite of marked differences in water quality between the different types of water supply, no relationship was found with diarrhoea morbidity. In contrast, there was a statistically significant association between water availability and diarrhoea morbidity. Children from homes with water supplies over 500 meters from the house had incidence rates of diarrhoea 34% higher than those of children from homes with their own water supply. Owning a latrine was not found to be significantly related to diarrhoea morbidity. A mother's level of schooling was inversely correlated with the frequency of diarrhoea in her children. A significant association was also found between the number of children under the age of five living in the house and the incidence of diarrhoea. These effects remained significant after controlling for confounding variables by conditional logistic regression.

It is well known that acute diarrhoeal disease is one of the most important causes of morbidity and mortality in children under five years of age. Mortality rates of over 20 per 1000 children in their first two years of life have been reported in Latin American countries and average morbidity rates are estimated at two episodes per year.¹

The use of oral rehydration therapy has been promoted to reduce diarrhoea mortality, recognizing that other strategies are necessary to reduce diarrhoeal morbidity.² In 1982, the Diarrhoeal Diseases Control Programme of the World Health Organization commenced a systematic study of the strategies that might play a role in the control of diarrhoea. One of the seven strategies considered to be viable was the improvement of water supplies and sanitation.³

However, the relationship between improvements in water supply or sanitation and diarrhoeal disease is

still not completely understood. Although reviews of more than 50 investigations on the relationship between diarrhoea and environmental sanitation found positive impacts in the majority,^{4,5} there was considerable variation in the magnitude of the effects observed. For example, while there was a median reduction of 25% associated with improvements in water availability, the impact ranged from 0% to 100%. Similarly, they found that the reduction in morbidity associated with water quality improvements ranged from 0 to 90% (median 16%).⁴

The presence of design faults in many of these studies could explain the lack of consistency in the results. Blum and Feachem⁶ identified eight important methodological flaws in the designs of 44 published studies and concluded that 'while most of the studies do claim to show an improvement in one or more health indicators, critical review of the papers raises serious doubts as to the validity of their conclusions'.

Since then, efforts have been made to develop rigorous methodologies to measure the health impact of strategies aimed at reducing diarrhoeal morbidity.⁷ The outcome of this has been the application of case-control designs whose superior efficiency in comparison with cohort studies, even for investigating common

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diseases, allows data of higher quality to be collected.⁸ This article presents results from one application of the case-control method to the study of the relationship between acute diarrhoeal disease and environmental risk factors.

METHODS

This study was undertaken in Villa Carlos Fonseca, a rural municipality located on the Pacific coast about 30 km from Managua, the capital of Nicaragua. Within its area of 500 square kilometres there are approximately 30 000 inhabitants distributed amongst 35 communities. There is one health centre (with a small laboratory but no beds) and six smaller health posts.

A random sample of houses registered with the Ministry of Internal Commerce's consumer census was visited in order to determine the prevalence of the different types of water supply and sanitation. A subsample was then selected of sites representative of each type of water source from which monthly samples were taken to measure microbiological water quality by faecal coliform count. The results from a multivariate analysis of the water quality data have been published elsewhere.⁹

Cases and controls were recruited from the health centre and five of the six health posts, matched by age and the health care facility where they were first seen. All children under the age of five presenting with diarrhoea (defined as four or more liquid motions per day, with or without mucus, fever or blood), were recruited as cases, provided that they had not been included in the study as cases or as controls within the previous seven days. Children presenting with other symptoms in addition to diarrhoea were included as cases as long as they fulfilled the criteria. A child could be recruited on more than one occasion as either a case or a control irrespective of the previous diagnosis, provided that it had not been included in the previous seven days. Each case was matched to one control, which was defined as the next child of the same age group presenting to that clinic with one or more of the following conditions:

- | | |
|---------------------------------------|--------------------|
| (a) Acute respiratory tract infection | (b) Measles |
| (c) Otitis | (d) Mumps |
| (e) Non-specific fever | (f) Skin disorders |
| (g) Malaria | (h) Conjunctivitis |
| (i) Urinary tract complaints | (j) Chickenpox |
| (k) Oral candidiasis | (l) Allergy |

Specifically excluded from the control group were children diagnosed as having hepatitis, typhoid or parasitosis, or presenting with nausea, stomach pains, breast-milk intolerance or mild diarrhoea. Children with any form of trauma were also excluded from the control group because it is believed that they may be

drawn from a different population than those who present with diarrhoea and thus their inclusion would introduce selection bias.⁸

At the health centre and each of the five health posts, a research assistant was employed to fill in the data forms, measure the child's height and weight, and to match controls with cases. Seven age categories were used for the purpose of matching (<1 month, 1-5 months, 6-11 months, 1 year, 2 years, 3 years and 4 years). The doctors and nurses staffing the clinics were responsible for making the diagnosis so they were also taught the selection criteria. Clinic data forms recorded a variety of information about the child, including its date of birth, age, sex, weight, height, type of feeding and diagnosis. Ownership of a latrine and drinking water supply were also noted to permit cross-checks with home visit data.

Field workers unaware of the subject's diagnosis were sent to the home of each child in order to verify by direct observation the type of water supply and presence or absence of a latrine. They reinterviewed the mother, asking once again the child's age and type of feeding but questions were also added to ascertain the parents' levels of schooling, their employment, and the number of household inhabitants (including the proportion under five years of age). Interviewers noted the distance from the house to the water supply and certain indicators of socioeconomic status such as the floor and roof construction materials, the types of domestic animal owned, and the possession of a radio, television, refrigerator, car, horse or cattle. If the child was normally cared for by someone other than the mother, data was collected from that person and if the mother or guardian was not at home a repeat visit was arranged. Where a family had already been visited within the three preceding months, the visit was not repeated unless the family had changed their address.

Least-squares linear models were fitted to identify the determinants of bacteriological water quality⁹ and household water consumption.¹⁰ The ratio of discordant pairs was used as an estimator of the incidence rate ratio for the different levels of each risk factor. The rate ratio was tested for statistical significance using McNemar's test in the first place and then by conditional logistic regression while controlling for confounding variables. The 95% confidence intervals were estimated by maximum likelihood.

RESULTS

Water Quality

The six main types of water supply identified in the population survey were rivers and streams, unprotected wells, protected wells, wells with mechanical

pumps.
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streams, rivers,
protected wells
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pumps, public standpipes and domiciliary connections. Unprotected wells include springs and generally consist of shallow holes dug at the bank of a river or gully. Protected wells are usually at least seven metres deep and are surrounded by a parapet with the water drawn in a bucket on a rope.

The (geometric mean) faecal coliform counts obtained from each type of water source are shown in Figure 1. There was a marked difference in the degree of contamination of piped water compared with water from wells or other traditional sources. It was surprising to discover that during periods of low rainfall, the water quality of the unprotected wells was better than that of protected wells. Water quality was worse during wet periods, especially in the unprotected wells. The results of the water quality analysis have been presented elsewhere.⁹

Relationships between Water Supply and Diarrhoea Morbidity

A total of 1229 cases-control pairs were recruited between May 1986 and March 1988. The recruitment of cases by month is shown in Figure 2. There is seasonal variation such that during the rainy season more cases of diarrhoea were recruited than during the dry season. The majority of cases were less than one year old and 80% were under two years of age. Home visit data was obtained for 2436 of the 2458 subjects (99.1%).

Table 1 shows the relative rates of diarrhoea for the risk factors investigated. Of these factors, only water availability, the level of maternal education and the number of under five year old children living in the house were significantly associated with diarrhoea morbidity. There was no indication that the presence of a latrine or the type of water source (a reasonable proxy for bacteriological water quality), were risk factors for diarrhoea.

Water availability was significantly associated with diarrhoea when included in the logistic regression model as a continuous variable, implying that the frequency of diarrhoea increases exponentially with unit increases in the distance from the house to the water source (Figure 3). Thus, in houses with water sources 500 metres away, children had 34% (95% CI 2-56%) more diarrhoea than in houses adjacent to their water supply.

Child diarrhoea morbidity was found to depend on the mother's level of schooling. Children of women with primary school education had 18% less diarrhoea than those of women with no formal education. The children of women with secondary school education suffered 26% less diarrhoea than those who had not attended school. There was no correlation between the incidence of diarrhoea and a father's level of education once the other variables had been included in the model.

It was also discovered that the rate of diarrhoea in

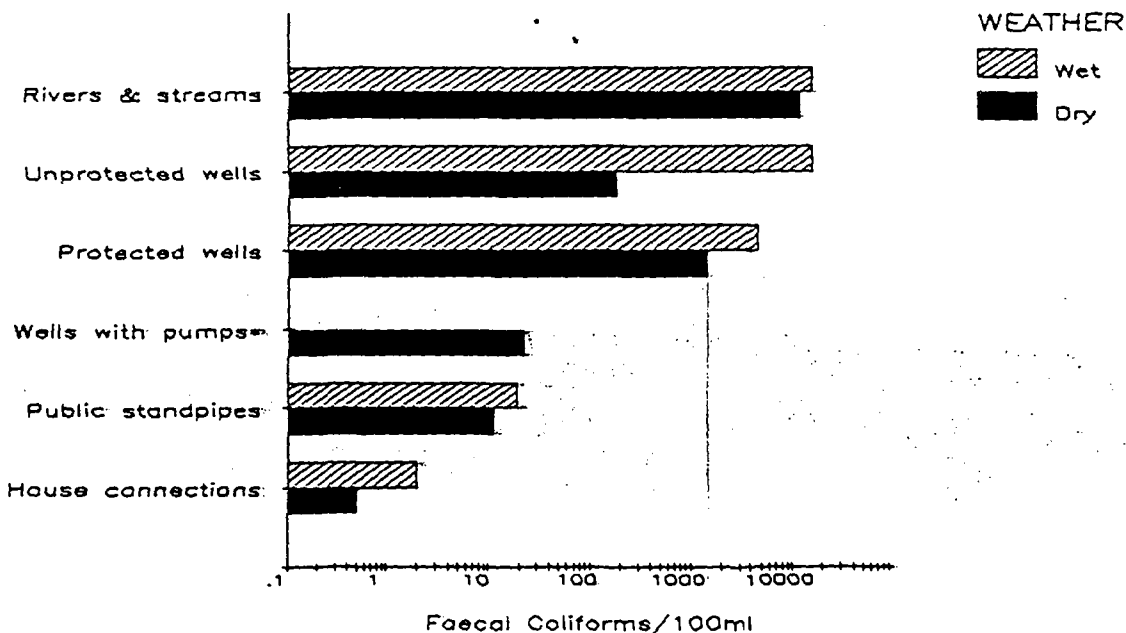


FIGURE 1 Geometric mean faecal coliform counts by type of water source during wet and dry weather (months with >200 mm rain defined as wet).
 * No samples were taken from wells with pumps during the wet period

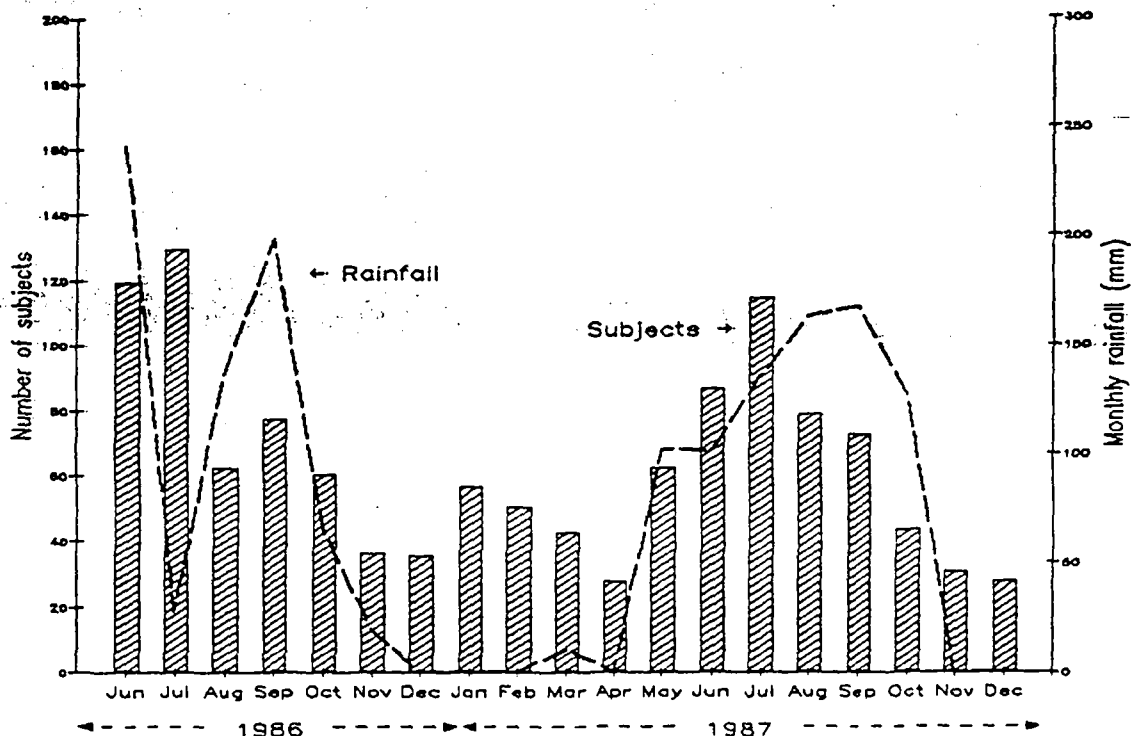


FIGURE 2 Monthly rainfall and recruitment of subjects.

houses with more than four children under five was 70% higher than in houses with just one under five year old. In houses with two to four children under five, the rate was 22% higher.

DISCUSSION

The results presented support the notion that access to water is an important risk factor for diarrhoea. Most studies have not attempted to obtain separate estimates for the impact of water quality and water availability, (indeed the two are often highly correlated making this difficult to achieve in practice), but there are two review papers which divide health impact evaluations of water supply into those where the improvement was predominantly in water quality, and those where the improvement was mainly in water availability. The first of these found that the median percentage reduction in diarrhoea incidence for studies where the improvement was mainly in water availability was 25% compared with 16% for those studies where the improvement was predominantly in water quality.⁴ The second paper which reviewed many of the same studies, showed that the highest proportion of studies reporting a positive impact were those where the intervention resulted in increased water availability.⁵ Our findings are consistent with these results as it was found

that high rates of diarrhoea occur in the houses with water sources more than 500 metres away. At distances under 500 metres, however, the effect of water availability is small.

Since these reviews there have been several case-control studies of diarrhoea and environmental sanitation.¹¹⁻¹⁵ Two of them^{11,12} assessed the joint impact of improved water supply (mainly water quality) and excreta disposal facilities compared with neither or just one of these interventions. These studies did not report statistically significant effects although they were the earlier case-control studies with rather small sample sizes.

Another study¹³ used mortality from diarrhoea as the outcome measure and detected a significant association with water availability. They also observed a lower mortality rate in families using treated water but this was not significant after controlling for confounding variables. Diarrhoea mortality was unrelated to sanitation.

The Lesotho case-control study¹⁴ showed an association between diarrhoea morbidity and latrine ownership which was statistically significant in crude analyses but not in the logistic regression analysis (although the odds ratio remained 0.76). Diarrhoea also showed crude associations with water consumption and with

TABLE 1

Risk factor	Statistical test
Type of water supply: piped vs. unprotected; river/stream	χ^2 (3 df)†
Distance to water source: < 50 m; 50-149 m; 150-249 m; 250-349 m; 350-449 m; 450-749 m; 750-1249 m; \geq 1250 m	χ^2 (1 df) trend
Presence of latrine: no latrine; latrine	χ^2 (1 df)
Maternal schooling: nil; primary; secondary	χ^2 (1 df) trend
No. children under five: 1; 2-4; \geq 5	χ^2 (1 df) trend

†Matched analysis of odds ratios.
‡The χ^2 statistic.
* $p < 0.05$; ** $p < 0.01$.

the type of water quality regression

In a case-control study of diarrhoea mortality from water source, the findings showed that more of waterborne disease such as faecal coliforms were associated with the presence of a latrine.

It is difficult to compare the relative importance of water availability or quality on the

TABLE 1 The distribution of diarrhoea cases and controls by exposure with crude and adjusted relative rates

Risk factor	Cases	Controls	Odds ratios		95% confidence Intervals
			Crude	Adjusted†	
Type of water source					
piped water supply	214	201	1.00	1.00	
protected well	521	562	0.86	0.92	(0.69-1.24)
unprotected well	407	382	1.01	1.11	(0.80-1.55)
river/stream	10	9	1.08	1.17	(0.37-3.67)
χ^2 (3 df)‡			3.16	4.32	
Distance to water source					
< 50 metres	713	751	1.00	1.00	
50-149 metres	249	230	1.12	1.16	(0.91-1.47)
150-249 metres	85	85	1.05	1.06	(0.74-1.50)
250-349 metres	38	44	0.93	1.00	(0.62-1.62)
350-449 metres	28	27	1.12	1.12	(0.63-1.98)
450-749 metres	12	4	3.79	3.61	(0.98-13.3)
750-1249 metres	14	8	1.78	1.80	(0.73-4.44)
≥1250 metres	13	5	2.69	3.29	(1.13-9.61)
χ^2 (1 df trend)			6.55*	7.24**	
Presence of a latrine					
no latrine	462	459	1.00	1.00	
latrine	690	695	0.98	0.99	
χ^2 (1 df)			0.05	0.01	
Maternal schooling					
nil	351	307	1.00	1.00	
primary school	687	720	0.84	0.82	(0.67-0.99)
secondary school	114	127	0.78	0.74	(0.54-1.02)
χ^2 (1 df trend)			4.01*	4.74*	
No. children under five years					
1	302	349	1.00	1.00	
2-4	810	778	1.20	1.22	(1.00-1.48)
≥5	40	27	1.68	1.70	(1.02-2.85)
χ^2 (1 df trend)			6.09*	6.00*	

†Matched analysis adjusting for potential confounders and all other main effects. The confounding variables controlled for were feeding practice, possession of a latrine, type of water source, socioeconomic status, access to health facilities and distance to health services.

‡The χ^2 statistic used is the score test.

* $p < 0.05$; ** $p < 0.01$.

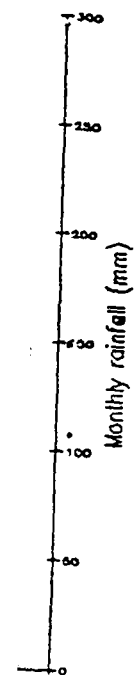
the type of water supply (which may be a proxy for water quality) but these were not analysed by logistic regression.

In a case-control study performed in Sri Lanka, diarrhoea morbidity was significantly related to the type of water source both before and after adjusting for confounders.¹⁵ The authors believe that this is an effect more of water quality than of water availability. When disease status was compared with geometric mean faecal coliform counts (adjusting for source and area) there was a small but statistically insignificant difference between cases and controls.

It is difficult to make any general statement about the relative importance of water quality, water availability or sanitation from these studies. Their importance may actually vary from one country to another

according to differences in geographical setting, behaviour patterns, transmission routes of the common aetiological organisms, or the nature of the water supplies and excreta disposal facilities. It is also possible that the inconsistencies derived from biases in one or more of the studies.

Our results suggest that the transmission of diarrhoea in Nicaragua is predominantly water-washed rather than water-borne. Where the prevention of diarrhoea is an important consideration in the design of water supply projects, the main focus should be on improving water availability and not water quality. It implies that the practice of boiling drinking water (advice frequently included in health education materials in Nicaragua) may be of little benefit. Taking into account the cost for the family of boiling water and

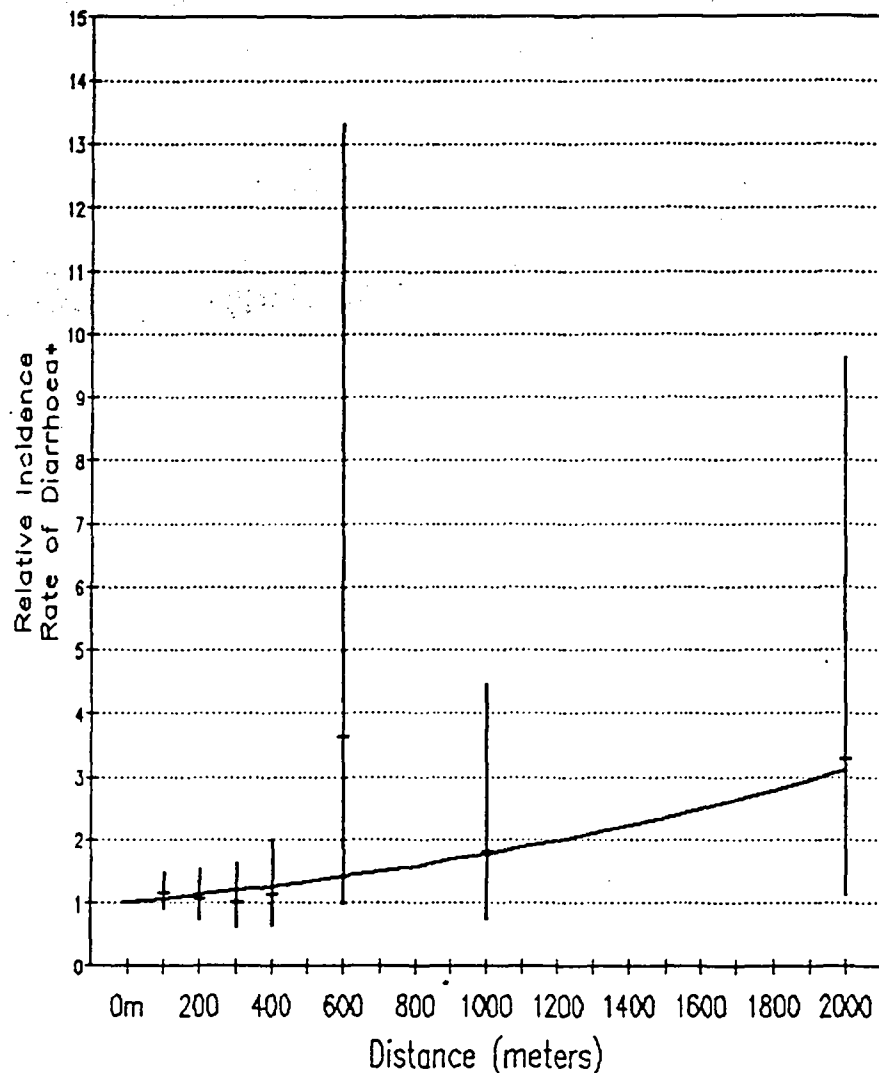


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* Compared with homes adjacent to their water supply

FIGURE 3 Relative rates of diarrhoea morbidity by distance from the home to the water source (point estimates, 95% confidence limits and trend line).

its other disadvantages,¹⁶ it may be wise to reconsider the inclusion of this advice in health education programmes. On the other hand, it was not possible in this study to assess whether the lack of an association between water quality (at the source) and diarrhoea was in part due to the practice of boiling water in the home. Recent observational studies performed in Villa Carlos Fonseca however, suggest that drinking water for infants is not usually boiled (unpublished results).

The strong association between maternal schooling and child health has been demonstrated previously in Nicaragua^{17,18} and elsewhere.¹⁹ Although the precise

mechanism by which child health depends on a mother's level of education is unknown, it is plausible that hygiene practice is important.²⁰ This is supported by the correlation found between per capita domestic water consumption and maternal schooling.¹⁰ It is possible that as well as using more water, educated mothers also dedicate a greater proportion of the water they collect to hygiene-related activities.

At this stage however, there is only indirect evidence for an association between hygiene practice and maternal schooling. Education is a complex social variable and its relationship with health could have several

components. A mother's education is closely associated with socioeconomic status, with access to health services, with intrafamilial power relationships, and with her health-seeking behaviour when the child is ill. The lack of a significant relationship between diarrhoea morbidity and paternal education in this study suggests that the effect of the mother's education is not merely a reflection of socioeconomic status. However, the influence of education on the behaviour of the mothers with their sick children could explain the observed relationship with diarrhoea. For example, if educated mothers give home-based oral rehydration therapy while uneducated mothers tend to seek professional help, diarrhoea morbidity will appear lower in the group of educated mothers. More research is needed to clarify the importance to child health of maternal literacy and education.

The higher rate of diarrhoea morbidity in houses with more children under the age of five requires little explanation. Secondary transmission of diarrhoea is obviously facilitated by person to person contact between the children in the house. Family planning programmes or improved housing may have some impact on diarrhoea incidence but the effect observed in this study was small except where more than four children under five years old lived in the house.

The results obtained from this study do not allow comment on the efficacy of other methods for preventing diarrhoea recommended by the World Health Organization, such as the promotion of breastfeeding, measles immunization or improvements in weaning practice.³ The study does suggest that improvements in water availability and hygiene education can be effective interventions for the prevention of child diarrhoea.

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