Tropical Medicine and International Health

VOLUME 1 NO 3 PP 334–341 JUNE 1996

Drinking water sources, mortality and diarrhoea morbidity among young children in Northern Ghana

R. P. Shier,[1] N. Dollimore[1,2], D. A. Ross[1,2], F. N. Binka[2,3], M. Quigley[1] and P. G. Smith[1]

[1] London School of Hygiene and Tropical Medicine, UK
[2] Ghana Vitamin A Supplementation Trials, Navrongo, Ghana
[3] Ministry of Health, Ghana

Summary In the Upper East Region of Ghana, considerable resources have been invested in the provision of boreholes. As part of the Ghana Vitamin A Supplementation Trials' Survival Study which was carried out in one of the districts of the Upper East Region between January 1989 and December 1991, data were collected over a period of one calendar year on the drinking water sources used by approximately 13 000 mothers/guardians of over 20 000 children and on the morbidity and mortality experiences of these children. These data were used to describe seasonal and geographical variations in drinking water sources; to look for other predictors of water source use; and to establish whether the drinking water source was associated with the risk of child death or the period prevalence of diarrhoea among young children.

Boreholes were used as the main source of drinking water by about 60–70% of respondents. They were used slightly more frequently in the dry season. In the rainy season, the use increased of more traditional sources such as rainwater or holes dug in stream beds. The use of boreholes was greatest in the northern zone of the study area and was more common in those who had had some formal education and were of higher socioeconomic status. Some association was found between reported drinking water source and diarrhoeal morbidity, although this association appeared to be seasonal. No significant association was found between drinking water source and child mortality.

keywords drinking water, boreholes, diarrhoea, child mortality

correspondence Dr David A Ross, London School of Hygiene and Tropical Medicine, Keppel Street, London WC1E 7HT, UK

Introduction

In many developing countries substantial investments have been made to provide and promote the use of safe water sources for domestic purposes. In rural areas, although some programmes have promoted 'protected' wells or springs, most have focused on the provision of boreholes. These are narrow diameter, deep wells, usually lined with a PVC casing and fitted with a hand-pump set into a concrete apron. In the water supply project in the Upper Regions of Ghana (Ghana Water Utilization Project 1990), approximately 2700 boreholes were constructed between 1973 and 1980. A programme of community involvement and education related to their use was started in 1977.

There were two principal justifications given in northern Ghana and elsewhere for providing boreholes: first, to improve accessibility to water, thereby increasing the quantity of water used. This should decrease the transmission of water-washed diseases, such as scabies, conjunctivitis and trachoma.

Secondly, to improve the quality of the water available, which should decrease the transmission of water-borne diseases, such as schistosomiasis and Guinea worm (Bradley & Emurwon 1968; Feachem 1977). The transmission of diarrhoea should be decreased by both mechanisms. Since transmission of the pathogens which cause diarrhoea is largely by the faecal–oral route, access to and appropriate use of greater quantities of water for hygiene purposes, especially hand washing, should reduce faecal–oral contamination and hence the transmission of diarrhoea. Improved water quality at consumption will decrease the number of pathogens consumed. It has been shown that the bacteriological quality of borehole water at source is relatively high compared to water drawn from traditional sources (Aziz *et al.* 1990; Moe *et al.* 1991; White *et al.* 1972). This is because the water is drawn from far below the surface and the source is completely covered, minimizing faecal contamination. Thus, one would expect the use of boreholes as the main source of drinking water to be associated with a reduction in transmission of diarrhoea. In regions such as the study area, diarrhoea is a major cause of death; hence a reduction in mortality rates might also be expected. However, the evidence to support this hypothesis is weak. In a review of 144 studies (Esrey *et al.* 1991), improved water quality was found to be associated with a reduction in diarrhoeal morbidity. However, several studies found little or no association. In two major studies published since this review, one (Manun'ebo *et al.* 1994) reported a significant association between diarrhoea incidence and drinking water source, whereas the other (Gorter *et al.* 1991) found no such association.

The Ghana Vitamin A Supplementation Trials' Survival Study (Ghana VAST Study Team 1993) provided an opportunity to assess the extent to which the large number of boreholes which have been provided in the area over the past 2 decades were being used, and whether or not their use for drinking water was associated with a lower diarrhoea prevalence or mortality among young children.

Subjects and methods

The Ghana Vitamin A Supplementation Trials (VAST) Survival Study was carried out in rural areas of the Kassena-Nankana district of the Upper East Region of Ghana. This is a Guinea savannah area with a long dry season and a single rainy season between May and September. The average rainfall is approximately 850 mm. The population lives in dispersed compounds, each consisting of a group of houses within a single outer wall and surrounded by its own farm land.

The Ghana VAST Survival Study has been described in detail elsewhere (Ghana VAST Study Team 1993). In summary, children aged between 6 months and 7 years who were resident in the study area were eligible for inclusion in the trial at each of a series of 7 4-monthly home visits (survey rounds), at which they were dosed with either vitamin A or placebo. In addition, at these visits, the mother or guardian of each child was asked whether her child had suffered from a list of 7 morbidity symptoms or conditions during the week immediately preceding that visit. These included diarrhoea and/or vomiting. Deaths among the study children were identified at the time of the 4-monthly visits and also through a network of approximately 90 informants.

In the final year of field-work for the study, corresponding to survey rounds 5, 6 and 7, data were collected on sources of drinking water. The mother or guardian of each child was asked by the field-worker where she had collected her drinking water from on the previous day. If she had collected water from more than one source, only the first source used on that day was recorded. At the start of that year, field-workers also recorded the location, number and status (whether fuctioning) or all boreholes, wells and stand-pipes in the area. Additional information available for each child included their parents' educational level, child's age and geographical zone (the study area was divided into 4 zones: North, South, East and West).

A wide variety of measures were used to maximize and check the quality of the data collected. In addition to frequent spot checks, supervisory visits and regular refresher training, blind re-interviews were conducted by the supervisors on a sub-sample within 48 hours of the original interview. Where there was a difference in any of the information collected, including drinking water source, the interviewer was asked to re-collect data from 5 compounds. If there were discrepancies on these,

Table 1 Reported sources of drinking water by survey round

Water source	Round 5 Feb–April (Hot dry season) No.	%	Round 6 June–Aug (Rainy season) No.	%	Round 7 Oct–Dec (Cool dry season) No.	%
Piped	30	0.2	42	0.3	62	0.5
Borehole	9011	67.1	8063	63.5	7416	59.8
Well	2955	22.0	2427	19.1	2680	21.6
Hole dug in stream bed	969	7.2	1728	13.6	1645	13.3
Other[1]	455	3.4	434	3.4	607	4.9
Total	13 420	100	12 694	100	12 410	100

[1] Other: Pond/dam, flowing stream/river, rainwater, or other (not specified).

extra training and supervision was given to the field-worker concerned and all their interviews for that cluster of children were repeated. The mapping of borehole and well data was checked by a specially trained supervisor.

Information on water sources was related to mortality rates and diarrhoeal prevalence for the year for which water source data were collected. Diarrhoea morbidity was assessed as the proportion of children who were reported to have had diarrhoea and/or vomiting (these symptoms were not asked about separately on the questionnaire) at any time during the week prior to the interview. Multiple logistic regression was used to compare the 1-week period prevalence in children using different water sources, adjusting for confounding factors such as age. A Poisson regression model was used to examine the association between drinking water source and mortality. For the purposes of this analysis, children were assumed to be exposed to the drinking water source reported at the most recent survey round until the next home visit. Thus, their follow-up between each pair of visits (survey rounds) was allocated to the appropriate exposure group at the time of the first of that pair of visits. The data were double-entered and processed using Dbase III+. Statistical analyses were carried out using Foxpro 2.0, SPSS PC+4.0, and Egret software.

Results

Water source data were available from over 12 000 informants in each of the 3 relevant survey rounds (rounds 5, 6 and 7). Boreholes were the most common source of drinking water throughout the year, used by 60% or more children's families in all three seasons, followed by wells and pits dug in stream beds (Table 1). Piped water was used by less than 1% in all 3 seasons, reflecting the scarcity of this supply. Most (97.2%) of the informants were female, and just over 80% of these were the mother of the study child. Reported drinking water source did not differ by the sex of the informant. Those informants in the youngest and oldest age groups (less than 20 years and 60 years or over, respectively) were slightly more likely to collect drinking water from a borehole (data not shown).

There were significant differences in the sources of drinking water used in the 3 survey rounds (χ^2-test for heterogeneity=448.1, 8 d.f., P<0.001, Table 1). The main difference was that the proportion getting their water from a pit dug in a stream bed during and after the rains was approximately double that during the driest period (Table 1 and Figure 1). The proportion using boreholes and wells also varied, with a higher proportion using these sources during the driest period (February–April).

There were substantial variations in water source use in the different zones of the study area (χ^2-test for heterogeneity=3849, 12 d.f., P<0.001, Table 2). These geographical variations can be explained by differences in the availability of the water sources. The number of working boreholes in each of the 4 zones was similar (Table 3). There were substantially more wells and stand-pipes in the northern zone

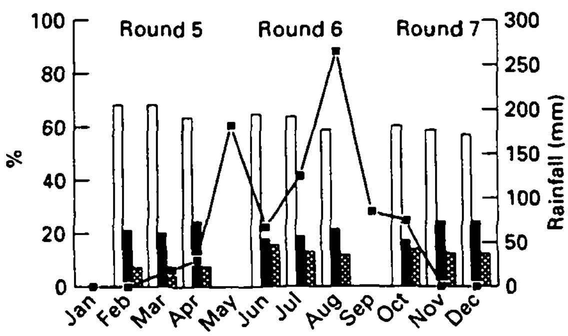

Figure 1 Use of drinking water sources by month and monthly rainfall. No data on sources were collected during January, May or September. —■—, Rainfall; □, borehole; ■, well; ⊞, stream bed.

(Table 3), and this was reflected in the higher use of these sources in that zone (Table 2). This was despite the fact that irrigated gardening was widespread in the northern zone and many of the wells in that zone were used almost exclusively for this purpose. Other factors associated with drinking water source (Table 2) were the mother's educational level ($\chi^2=244.2$, 4 d.f., $P<0.001$), her husband's educational level ($\chi^2=201.2$, 4 d.f., $P<0.001$), and markers of socioeconomic status—whether any of the houses in the compound had a zinc roof ($\chi^2=364.1$, 4 d.f., $P<0.001$) and whether anyone in the compound owned a radio ($\chi^2=398.9$, 4 d.f., $P<0.001$). In general, children whose mother or father had had some education or who lived in a compound which had at least one building with a zinc roof or where at least one person owned a radio, were less likely to take their drinking water from a stream bed, but were more likely to have access to piped or borehole drinking water.

Drinking water source and child mortality and diarrhoea morbidity

During the year of the water source study, 271 of the children in the trial population died. These deaths were classified according to the drinking water source reported in the survey round prior to the death of the child (Table 4). Children whose drinking water source was a hole dug in a stream bed had the highest mortality rate, but this was not significantly higher than the mortality rates associated with other water sources ($\chi^2=2.6$, 3 d.f., $P=0.5$). This remained the case after adjusting for age, geographical zone, possession of a radio and parents' education ($\chi^2=2.9$, 3 d.f., $P=0.4$).

The reported period prevalence of diarrhoea varied by season, being greatest in the rainy season (Table 5). The variation in diarrhoea prevalence according to water source also differed in the three survey rounds. In the hot dry season (round 5), those using a borehole had a lower prevalence than those using any of the other sources, apart from the few with access to piped water, whereas in the rainy season (round 6), the crude prevalence of diarrhoea was highest in those whose drinking water source was a borehole. The odds ratios for diarrhoea prevalence associated with the different water sources differed significantly across the 3 dosing rounds ($\chi^2=31.5$, 8 d.f., $P<0.001$). Only within the hot dry season (round 5), however, were the adjusted (for age group and geographical zone) odds ratios associated with different water sources significantly different from each other (hot dry season: $\chi^2=32.1$, 4 d.f., $P<0.001$; rainy season: $\chi^2=5.75$, 4 d.f., $P=0.2$; cool dry season: $\chi^2=8.1$, 4 d.f., $P=0.09$).

Discussion

Throughout the year, boreholes were used by over half the respondents (60–70%), and wells by approximately one-fifth (19–22%), but substantial numbers of respondents reported using holes dug in stream beds (7–14%), especially during and immediately after the rainy season (Table 1). This finding confirms the results from studies in other developing countries which have reported that fewer people use boreholes and wells as the rainy season progresses (Aziz *et al.* 1990; Lindskog & Lundqvist 1989; Blum *et al.* 1987a). This suggests that accessibility may be an overriding factor in the choice of water source for many families. It underlines the importance of provision of safe sources of drinking water such as boreholes as near as possible to households.

The observed differences in reported drinking water source by the age of the informant could be due to differences in awareness. The youngest women will probably have been the best informed about safe water through education or the media.

Table 2 Reported sources of drinking water (summed over the three survey rounds) by study zone, parental education, type of roof, and radio ownership

Variable		No.	Drinking water source (%) Piped	Borehole	Well	Stream bed	Other
Zone	East	9218	0.03	67.7	10.0	18.5	3.7
	North	11 346	1.0	53.2	33.6	7.6	4.5
	South	9830	0.2	70.7	10.0	15.4	3.7
	West	8728	0.0	64.2	28.4	3.8	3.6
Mother's education [1]	None	31 070	0.2	63.5	20.3	12.1	3.9
	Some	3677	1.2	63.1	25.5	6.1	3.9
Father's education	None	29 880	0.2	62.8	20.9	12.1	4.0
	Some	4771	1.0	67.4	21.3	7.3	3.0
Zinc roof	No	28 597	0.1	62.2	21.4	12.3	4.0
	Yes	10 344	1.1	67.1	19.7	8.5	3.6
Radio ownership	No	27 120	0.1	62.5	20.1	13.1	4.2
	Yes	11 786	0.8	65.8	22.9	7.5	3.0

[1] Restricted to informants who were the mother of the study child.

Table 3 Number of boreholes, wells and standpipes by geographical zone

Zone	Boreholes Total no.	Functioning No.	%	Wells Total no.	Functioning No.	%	Standpipes Total no.	Functioning No.	%
East	50	40	80	262	199	76	11	2	18
North[1]	51	39	76	1192	1156	97	30	29	97
South	49	44	90	227	177	78	9	8	89
West	50	37	74	245	228	93	14	1	7

[1] Irrigated gardening was widespread in the north zone and many of the wells in that zone were used almost exclusively for this purpose.

The oldest group of women were less likely to have collected the water themselves, and were probably reporting the water source chosen by their daughter or granddaughter, in which case they would also have been reporting the choices of a young age group.

There was some evidence that water source was associated with the one-week period prevalence of diarrhoeal morbidity during the hot dry season which precedes the rains, with use of borehole and piped drinking water being associated with lower prevalences. With one exception, the odds ratios relative to the odds of diarrhoea in the borehole users were all very close to unity in the rainy season and during the cool dry season which follows the rains (Table 5). The exception was that users of water from a hole dug in a stream bed had the lowest odds of diarrhoea during the rainy season (Table 5). A possible explanation for this could be that the difference in quality between the water

Table 4 Mortality rates and rate ratios by drinking water source

Water source	Deaths	Follow-up (child-years)	Mortality rate	Crude rate ratio (95% CI)	Adjusted rate ratio[1] (95% CI)
Piped[2]	0	28.0	0.0	–	–
Borehole	176	7704.3	22.8	1.00 –	1.00 –
Well	58	2455.5	23.6	1.04 (0.77, 1.40)	1.02 (0.75, 1.39)
Stream bed	32	1242.5	25.8	1.13 (0.78, 1.65)	1.06 (0.74, 1.59)
Other	5	401.1	12.5	0.54 (0.22, 1.32)	0.54 (0.22, 1.31)
Total	271	11 831.3	22.9	–	–

[1] Adjusted for age group, zone, possession of a radio, and parents' education.
[2] Rate ratios not calculated because of the small number of child-years of follow-up in this group.

Table 5 One week period prevalence of diarrhoea by water source, and crude and adjusted odds ratio

Dosing round	Water source	Diarrhoea cases	Prevalence (%)	Crude OR	(95% CI)	Adjusted[1] OR	(95% CI)
Feb–Apr 1991 (Hot dry season)							
	Piped[2]	3	10.7	0.38	(0.11, 1.22)	0.42	(0.12, 1.43)
	Borehole[2]	3059	25.6	1.00	–	1.00	–
	Well	1080	27.1	1.08	(0.99, 1.17)	1.13	(1.04, 1.24)
	Stream bed	408	31.8	1.38	(1.22, 1.56)	1.38	(1.21, 1.58)
	Other	166	29.2	1.19	(0.98, 1.43)	1.20	(0.99, 1.45)
Jun–Aug 1991 (Rainy season)							
	Piped[2]	16	28.1	0.67	(0.38, 1.20)	0.84	(0.46, 1.53)
	Borehole[2]	4358	36.9	1.00	–	1.00	–
	Well	1277	35.8	0.95	(0.88, 1.03)	1.02	(0.93, 1.11)
	Stream bed	888	34.9	0.91	(0.83, 1.00)	0.87	(0.79, 0.96)
	Other	240	36.5	0.97	(0.82, 1.14)	1.01	(0.85, 1.20)
Oct–Dec 1991 (Cool dry season)							
	Piped[2]	15	17.0	0.77	(0.44, 1.35)	1.05	(0.59, 1.89)
	Borehole[2]	2304	21.0	1.00	–	1.00	–
	Well	809	20.6	0.98	(0.89, 1.07)	1.09	(0.99, 1.20)
	Stream bed	544	22.6	1.10	(0.99, 1.22)	1.08	(0.96, 1.10)
	Other	191	22.5	1.09	(0.92, 1.29)	1.18	(0.99, 1.40)

[1] Adjusted for age group (6–23, 24–47, 48+ months) and zone.
[2] Borehole rather than piped water was used as the baseline group, because of the small number of child-years of follow-up in the piped water group.

sources was less marked during the rainy season; studies in other parts of Africa have shown that unprotected sources become less polluted during the rains (Lindskog & Lundqvist 1989; Blum *et al.* 1987a). We collected no data on water quality so this could not be assessed directly in our own study area. An alternative explanation might be that diarrhoea transmission routes other than via water (e.g. food storage, flies) may assume greater importance during the rainy season.

Since the study of water sources was not the primary aim of this research project, the data available for the analysis of the associations between water source and health outcomes have limitations. No data were collected on water quality, water quantity, water storage or distance to water sources. All of these may be important explanatory factors in the relationship between water source and diarrhoea (Kolsky 1993; Mertens *et al.* 1990; Blum *et al.* 1987b; Lindskog & Lundqvist 1989). Furthermore, the data on both the water source and one-week period prevalence of diarrhoea were collected from each informant on only 3 occasions during the year, and they give a limited picture of the overall pattern of both the water sources used and the diarrhoea experience of each child. Also, only the first drinking water source which was reported to have been used on the day prior to the interview was recorded. Although most informants reported using only one source, some reported more than one. Therefore, even if most of their drinking water had been collected from a borehole, for example, the child and its family might have also been drinking water from other sources, and/or using water from these sources for other domestic purposes such as washing or cooking. A further limitation is that children may have drunk water collected by someone other than the informant. Finally, it is possible that respondents tended to give what they perceived to be the 'correct' answer to the question on drinking water source, rather than reporting the actual source used. If this had occurred, it would have biased the reported use of boreholes upwards. Although this cannot be ruled out, the magnitude of any bias was likely to have been decreased by the fact that the question on drinking water source was one of many questions asked at each interview, in a study where the main focus was not on water. Furthermore, the institution responsible for the research was not involved in any other activities related to water supplies.

Despite these limitations, it does appear that after substantial investment in borehole programmes in this area, most families were collecting their drinking water from boreholes. Nevertheless, the provision of boreholes did not necessarily ensure their use throughout the year, with some families preferring to use traditional sources such as holes dug in stream beds when these became easily accessible during and after the rainy season. There was no evidence that the source of drinking water was associated with child mortality rates in this study. The association between drinking water source and diarrhoea prevalence varied according to the season, with evidence that in the hot dry season the use of boreholes was associated with a lower prevalence. This association was less marked during the cool dry season and absent in the rainy season, perhaps because the differences between sources in terms of water quality were less marked than in the hot dry season, or because other transmission routes unrelated to water may assume greater importance during and after the rains.

Acknowledgements

The Ghana Vitamin A Supplementation Trials' (VAST) Survival Study was a collaborative research project between the London School of Hygiene and Tropical Medicine and the School of Medical Sciences of the University of Science and Technology, Kumasi, Ghana, with support from the Ministry of Health of Ghana. The project was funded by the Health and Population Division of the UK Overseas Development Administration. Preliminary exploratory studies were supported by the Wellcome Trust and Save the Children Fund (UK).

We thank the population of the Kassena-Nankana District and their leaders for their enthusiastic participation in the project; all the VAST field, computing, administrative and support staff for their dedication, particularly Seidu Nchor who supervised the mapping of all the wells and boreholes; the many colleagues in Ghana and London who supported the trial; and Sharon Huttly, Simon Cousens and Saul Morris who commented on earlier drafts of this paper.

Field work was carried out in the Kassena-Nankana district of northern Ghana; statistical analyses were made at the London School of Hygiene and Tropical Medicine.

References

Aziz KMA, Hoque BA, Huttly SRA *et al.* (1990) Water supply, sanitation and hygiene education—report of a health impact study in Mirzapur, Bangladesh. UNDP/World Bank Water and Sanitation Program, Washington DC.

Blum D, Feachem RG, Huttly SRA *et al.* (1987a) The effects of distance and season on the use of boreholes in northeastern Imo State, Nigeria. *Journal of Tropical Medicine and Hygiene* 90, 45–50.

Blum D, Huttly SRA, Okoro JI *et al.* (1987b) The bacterial quality of traditional water sources in north-eastern Imo State, Nigeria. *Epidemiology and Infection* 99, 429–437.

Bradley DJ & Emurwon P (1968) Predicting the epidemiological effects of changing water sources. *East African Medical Journal* 45, 284–291.

Esrey SA, Potash SB, Roberts L & Shiff C (1991) Effects of improved water supply and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infecton, schistosomiasis and trachoma. *Bulletin of the World Health Organization* 69, 609–621.

Feachem RG (1977) Water supplies for low-income communities: resource allocation, planning and design for a crisis situation. In *Water, Wastes and Health in Hot Climates.* (eds RG Feachem, M McGarry & D Mara) John Wiley, Chichester, 75–95.

Ghana VAST Study Team (1993) Vitamin A supplementation in northern Ghana: effects on clinic attendances, hospital admissions, and child mortality. *Lancet* 342, 7–12.

Ghana Water Utilization Project (1990) *Ghana Water Utilization Project (CIDA project 400/10971). 1990/91 Work plan—Transition Phase.* Unpublished mimeo; Ghana Water Utilization Project, Bolgatanga, Ghana.

Gorter AC, Sandiford P, Smith GD & Pauw JD (1991) Water supply, sanitation and diarrhoeal disease in Nicaragua: results from a case control study. *International Journal of Epidemiology* 20, 527–533.

Kolsky P (1993) Diarrhoeal diseases: Current concepts and future challenges. Water, sanitation and diarrhoea: the limits of understanding. *Transactions of the Royal Society of Tropical Medicine and Hygiene* 87(Suppl 3), 43–46.

Lindskog P & Lundqvist J (1989) *Why Poor Children Stay Sick—The Human Ecology of Child Health and Welfare in Rural Malawi.* Scandinavian Institute of African Studies, Uppsala (Research Report no. 85).

Manun'ebo MN, Haggerty PA, Kalengaie M *et al.* (1994) Influence of demographic, socio-economic and environmental variables on childhood diarrhoea in a rural area of Zaire. *Journal of Tropical Medicine and Hygiene* 97, 31–38.

Mertens TE, Fernando MA, Marshall TF de C *et al.* (1990) Determinants of water quality, availability and use in Kurunegala, Sri Lanka. *Tropical Medicine and Parasitology* 41, 89–97.

Moe CL, Sobsey MD, Samsa GP & Mesolo V (1991) Bacterial indicators of the risk of diarrhoeal disease from drinking water in the Philippines. *Bulletin of the World Health Organization* 69, 305–317.

White GF, Bradley DJ & White AU (1972) *Drawers of Water: Domestic Water Use in East Africa.* University of Chicago Press, Chicago.

