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WATER SUPPLY AND DIARRHOEA IN AN EAST AFRICAN COMMUNITY

A case-control study on the quality of water supplies and the occurrence of diarrhoea among small children in a rural area of Western Kenya

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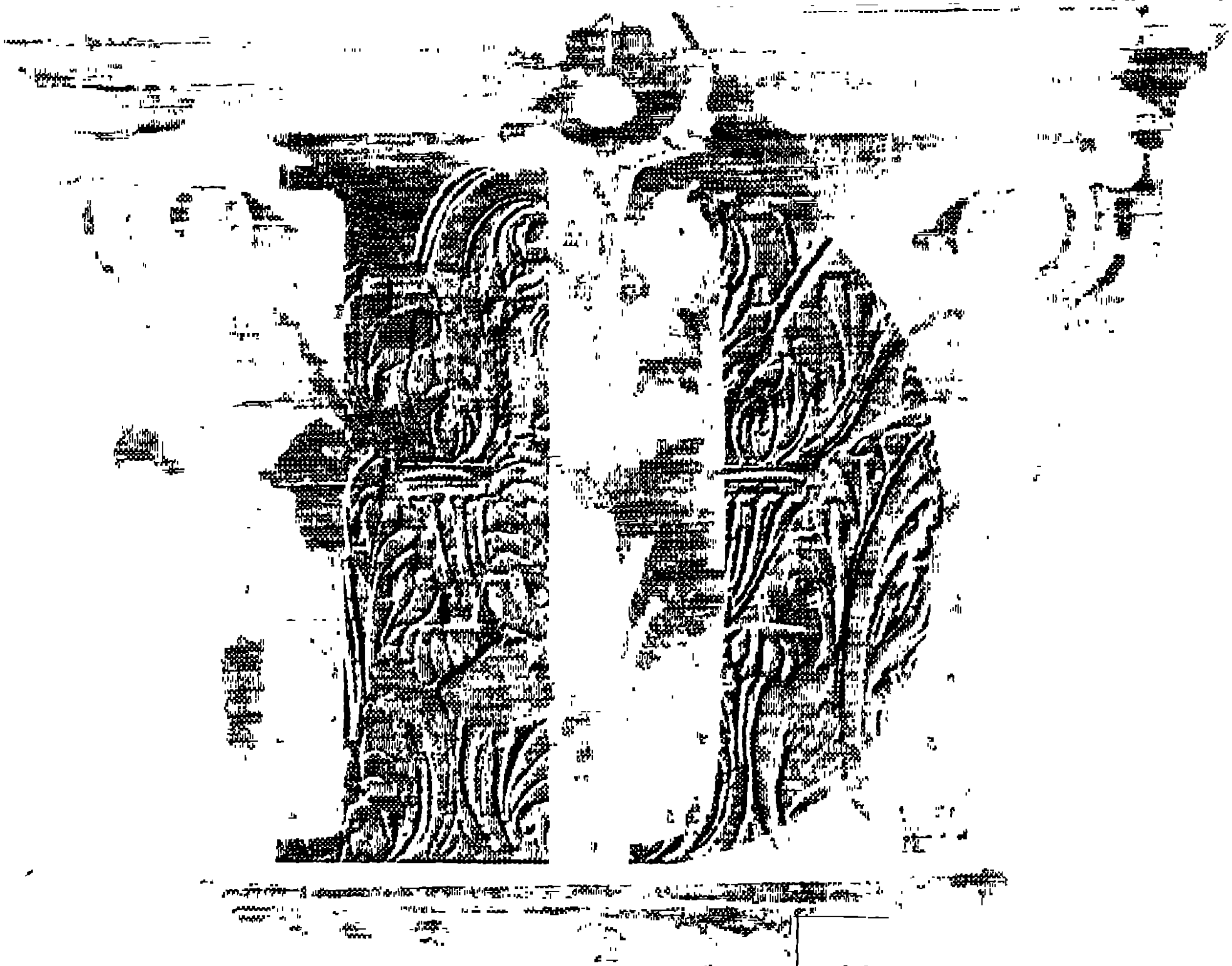

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Academic Dissertation to be presented with the assent of the Faculty of Medicine, University of Oulu, for public discussion in the Auditorium of Oulu Regional Institute of Occupational Health (Aapistie 1), on October 28th, 1994, at 12 noon.

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Kipua kinyemi, ingawa kidonda
A new thing is a source of joy even if it be a sore
Swahili proverb

To the Kenyan children and their families

Blanco Sequeiros, Marjatta, Water supply and diarrhoea in an East African community. A case-control study on the quality of water supplies and the occurrence of diarrhoea among small children in a rural area of Western Kenya
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Abstract

An assessment was made in the Western Province of Kenya of the effect of improved water sources on the occurrence of diarrhoea in children under five years of age. A total of 1129 children, 502 with diarrhoea and 627 controls with acute respiratory infection, reporting to six health centres during the rainy season of March–April 1991, were admitted to this case-control study. The parameters examined were water source, quantity of water used, and distance of the water source from the home, together with certain variables not directly related to water supplies.

The use of an improved water source was associated with a small decrease in the occurrence of diarrhoea (odds ratio, OR 0.80) in the whole material, a significant decrease occurred only in children at low risk with reference to age, hand-washing hygiene and feeding patterns. The use of surface water increased the occurrence of diarrhoea compared with the use of other water sources (OR 1.59). Location of the water source >500m from the home carried an increased risk relative to location ≥ 500 m from the home (OR 1.36).

Washing the hands before meals protected children aged 1–5y highly significantly against diarrhoea (OR 0.37). The occurrence of diarrhoea was not related to the use of a latrine, the quantity of water used, or the mother's age, level of education and number of children.

Alongside the case-control study, contamination was examined in 255 water sources during the dry season and 189 during the rainy season. Heavy contamination with faecal coliforms occurred in 10% of the unprotected and protected springs and in 23% of the shallow wells during the rainy season and in none of the boreholes.

Water stored at home was examined in 210 households. Contamination with Enterobacteriaceae occurred in 76% of them.

Washing the child's hands before meals emerged as the strongest protective factor against diarrhoea in children aged 1 to 5 years. If the child's hands were washed before meals, a further decrease in the occurrence of diarrhoea was noted upon the use of an improved water source.

Keywords: enteric disease, water source, hand washing, distance from water, water contamination.

ACKNOWLEDGEMENTS

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Oulu, September 1994 Marjatta Blanco Sequeiros

DEFINITIONS USED FOR TYPES OF WATER SOURCE

Unimproved

– surface water	river, lake, pond, dam, pool
– unprotected spring	a natural spring without any protective structure built around it, exposed to external contamination

Improved

– protected spring*	a natural spring protected with impervious material an all sides and on the surface in order to prevent contamination with surface water. Water collects in the chamber of the spring on account of the concrete retaining wall and is distributed through an outlet pipe
– shallow well*	a hand-dug well lined with concrete culverts or bricks, with a protective cover and a hand pump installed
– borehole*	a borehole well with hand pump
– roof catchment	rain water collected from a roof by a rain pipe into a concrete storage tank with an outlet pipe
– piped water	piped community water scheme

* see figures 1, 2 and 3 in Appendix 4

ABBREVIATIONS

aOR	adjusted odds ratio (logistic regression analysis)
ARI	Acute Respiratory Infection
c.f.u.	colony forming units
CI	95% confidence interval
FINNIDA	Finnish International Development Agency
IMR	infant mortality rate
n.	number
OR	odds ratio (univariate analysis) estimate of risk ratio ratio of the odds on exposure among the diseased relative to that among non-diseased individuals
p	p-value, probability of null hypothesis
RR	risk ratio or relative risk
VIP latrine	Ventilated Improved Pit Latrine

CONTENTS

1. BACKGROUND

Kenya lies in East Africa between longitudes 34° E and 42° E and latitudes 4° N and 4° S. It covers an area of approximately 582,650 sq.km, of which only less than one third is arable land. The country is bordered by Ethiopia and Sudan to the north, Somalia and the Indian Ocean to the east, Uganda to the west and Tanzania to the south (Map 1). Kenya consists of eight administrative areas, called provinces. The Western Province lies on the Equator, bordering on Nyanza Province and Lake Victoria to the south, Mount Elgon to the north, Uganda to the west and the Nandi Escarpment to the east. It has an area of 8223 sq.km. Most of the province is fertile, with loam and black cotton soils. Its altitude ranges from about 1100 m above see level on the shore of Lake Victoria up to 4300 m on the peaks of Mount Elgon. It receives a favourable rainfall, varying from about 750 to over 1800 mm per year, and several rivers flow through the province from Mount Elgon and Nandi Escarpment to Lake Victoria. The areas studied here are located at altitudes of 1120 m (Sio-Port) up to 1800 m (Kabuchai). Although there is a good potential for groundwater in the province, the dependence on surface water for drinking purposes was higher than the national average in 1989 (National Council for Population and Development 1989).

The total population of Kenya was estimated to be 24 million in 1990, of which children under 15 years of age accounted for 51% and those under 5 years of age 21%. The population of Western Province was estimated to be 2.4 million in 1990, of which children under 5 years made up 27% and children under 15 years 64% (projection based on the 1979 census, assuming constant levels of fertility and mortality; Republic of Kenya 1982). The main ethnic group in the province is the Luhya, others are the Teso and Sabaot, together with the Luo on the lakeshore. Economically, the province is mainly dependent on agriculture and it is a densely inhabited area (mean 292 inhabitants/sq.km).

The information available on morbidity and mortality in Kenya is incomplete. Few population-based morbidity surveys have been conducted; and the information regarding the utilization of health facilities suffers from incomplete and erratic submission of reports and varying levels of diagnostic accuracy. Registration data on births and deaths are not readily available, and in most cases estimates of morbidity and mortality have to be based on population estimates projected from an old census, which naturally increases the inaccuracy in a country with rapid population growth and significant internal migration.

In the Western Province the estimates of infant mortality (in 1979–89 Kenya 59/1000, Western Province 75/1000) and mortality under five years (in 1979–89 Kenya 91/1000, Western Province 133/1000) are above the national level and the fertility rate has remained at a high level (National Council for Population and Development 1989).

In order to develop the rural water supply and thereby promote improvement of the health of the population, a bilateral water project for a substantial part of the province was initiated by the Kenyan and Finnish Governments in 1983. The Kenya-Finland Western Province Water Supply Project has concentrated mainly on building shallow wells, boreholes and protected springs in rural areas. Relatively few repairs to gravitation schemes and water plants have been implemented by the project. The technology was adapted as much as possible to the prevailing conditions, and community involvement and training in the maintenance of hand pumps was developed at the village level.

With the initiation of the Kenya-Finland Primary Health Care Programme in Western Province in 1984 a synergic impact of water and health projects on health education, community involvement and improvement of the health status of the population was sought. The primary health care programme comprised the whole province with it's three districts but had limited target areas for certain activities. The programme consisted of training the staff of health facilities, traditional health workers and community health workers in primary health care and the construction, renovation and maintenance of health facilities, support in the building of VIP latrines in households and public places, health education and research. The rationale for the proposal of the allocation of the two projects to the same province was the assumption that there is a connection between health status and water supply. However, the geographical areas of the two separately administred projects were not identical and during the years the mutual co-operation has varied in the intensity.

After nearly ten years of continuous work on improving the water supply and primary health care with the support of two separate projects, it was interesting to study the impact of the improved water sources on the health of the population. Since diarrhoea is recognized as a water-related disease and small children are considered a vulnerable group, acute diarrhoea in children under five years of age was selected as an indicator reflecting the impact of various water sources on health. The complex interaction of biological, environmental, social and behavioural determinants in the occurrence of diarrhoea was taken into account when carrying out the research.

2. REVIEW OF THE LITERATURE

2.1. Diarrhoeal disease and water supply in the developing countries including Kenya

2.1.1. Diarrhoeal disease

Since the classical work of John Snow, who recognized the link between poor water supply and cholera infection in London in 1854 (Snow 1855), a considerable improvement in access to sufficient clean water and the hygienic disposal of excreta has taken place in the developed countries. Communicable diseases, specifically water and excreta-related ones, are no longer a major public health problem in the industrialized countries, except when large natural or man-made catastrophes occur. It is generally assumed that improved water supplies and proper sanitation (disposal of human excreta) reduce the incidence of diarrhoea and other water-borne diseases by reducing the transmission of enteric pathogens. Findings in the developing countries, however, have not consistently shown any clear positive effect of improvements in water supplies and sanitation on the health status of the population when measured in terms of diarrhoea among children under five years of age.

Diarrhoeal disease is a major cause of sickness in most developing countries. An estimated global median incidence rate for the developing countries of Africa, Asia and Latin America, based on cross-sectional surveys in 70 developing countries in 1989, was 3.4 episodes of diarrhoea per child under five years of age per year, the figure in Africa being as high as 4.4 episodes per year (World Health Organization 1990a, 1990b). Data based on a review of research after 1980 gave a diarrhoea incidence of 2.6 episodes per child per year (Bern *et al.* 1992). The total number of deaths due to diarrhoea in children under five years in the developing world, excluding the People's Republic of China, was estimated to be 4 million per year (Huttly 1990), and in a later review 3.3 million per year (Bern *et al.* 1992). A mortality estimate from the same sources yields a diarrhoea death rate of 12 per thousand of population under 5 years of age in the developing world, and 17.4 per thousand in Africa (Huttly 1990). The age-specific rates in the developing countries are highest in the first two years of life (Huttly 1990, Bern *et al.* 1992). In rural Zaire the risk of death three months after an episode of diarrhoea among preschool children without malnutrition was 2.4 relative to symptomfree children (Broeck *et al.* 1993).

Diarrhoeal diseases were reported to be a major cause of death in Kenya, accounting for 12% of all deaths in children under five years of age in 1978 (Republic of Kenya, 1990). The total mortality among children under 5 years of age during 1979–1989 was reported to be 91 per thousand live births (National Council for Population and Development, 1989).

Diarrhoea was the second most significant cause of childhood morbidity after respiratory infections, with a prevalence rate of 6.7% and an average of 4 annual episodes/year/child in 1989. The prevalence rate in Western Province was 10.5% (National Council for Population and Development, 1989). The Diarrhoeal Disease Management Survey in six districts of Kenya in 1990 reported a diarrhoea prevalence rate of 4.0–7.7% and 3.3–5.8 diarrhoea episodes/child/year. An annual incidence of 5.5 episodes/child/year was recorded in Kakamega district, the second highest among the six districts surveyed (Republic of Kenya, 1990).

A prospective longitudinal demographic and disease surveillance study in Machakos District in 1974–1977 recorded a two-weekly incidence of diarrhoea of 10.5% in children under five years of age. Diarrhoea mortality accounted for 15% of all deaths of children under five years of age in 1974–1977 (Leeuwenburg *et al.* 1984, Omondi-Odhiambo *et al.* 1984). No seasonal variation in diarrhoea morbidity was found in Machakos District, but there was a clustering of mortality in the period from March to July (Leeuwenburg *et al.* 1984).

In a household survey carried out in three sublocations of Western Province in June 1984, diarrhoea was the most commonly reported disease after respiratory infections, accounting for 15.4 % of all diseases reported among 502 children under five years of age (Water, Sanitation and Health Care Survey, 1986).

Diarrhoea was the third most frequent in-patient diagnosis after malaria and anaemia in children under ten years of age in hospital reports from St. Elizabeth Hospital, Kakamega District, in 1989 and 1990, and also the third most common cause of death among inpatients of that age (St. Elizabeth Hospital, Annual Report 1989, 1990).

2.1.2. Water supply

According to a recent review of water supply and sanitation, the worldwide coverage of improved water supplies in the less developed world (excluding the People's Republic of China) was close to 42% of the population in 1985 (Esrey *et al.* 1990).

The Diarrhoeal Disease Household Case Management Survey in Kenya (Republic of Kenya 1990) estimated that 18% of the rural population were dependent on wells for their water supply and 44% on rivers. Likewise a survey of 349 households in three sublocations of the Western Province recorded that 61% of them had an inadequate water source, i.e. a pool/dam, river/stream/lake, or unprotected spring (Water, sanitation and health care survey, 1986), while the Demographic and Health Survey reports that 63% of women in the Western Province of Kenya depended on a river, lake or pool as their water source in 1989 (National Council for Population and Development, 1989).

2.2. Aetiology of diarrhoea

Reports on the causative agents associated with acute diarrhoea among children reveal a wide range of viral, bacterial and parasitic causes, and although our aetiological knowledge of diarrhoea among children has increased greatly in recent years, about 30–50% of cases are still of unknown aetiology (Guerrant *et al.* 1986). Estimates of causative agents compiled from different sources vary considerably (Black *et al.* 1980, Black *et al.* 1982a, Black *et al.* 1989, Echeverria *et al.* 1989, Guerrant *et al.* 1983, Guerrant *et al.* 1986, Guerrant *et al.* 1990, Huilan *et al.* 1991, Mertens *et al.* 1990d, Weikel *et al.* 1985). Most reports are based on hospitalized cases and few on out-patients. The latest available estimates of the infectious aetiology of acute diarrhoea in developing areas are presented in Table 1.

Table 1. Percentage contribution of recognized causative agents to acute diarrhoea among children.

Aetiology	Guerrant *et al.* 1990	Huilan *et al.* 1991*
Rotaviruses	5–45%	16%
Norwalk-like viruses	1–2%	3%
Enteric adenoviruses	5–10%	4%
Enteropathogenic E.coli	4–8%	9%
Enterotoxigenic E.coli	7–50%	16%
Campylobacter	2–14%	11%
Shigella	5–16%	11%
Salmonella	0–15%	3%
Yersinia, Vibrio, Aeromonas, Clostridium difficile	1–6%	1%
Cryptosporidium	4–11%	no data
Giardia	5–20%**	3%
Strongyloides	5%	no data
Entamoeba histolytica	2–15%	0,3%

* in some instances two or more agents were isolated from the same individual
** in children <4 years old

The material of Huilan *et al.* comprised 3640 cases of diarrhoea and 3279 matched controls, aged 0–35 months, in five hospitals in China, India, Mexico, Myanmar and Pakistan. A pathogenic agent was detected in 68% of the diarrhoea cases, a bacterial agent in 48%, a viral agent in 23% and G.lamblia in 3% of cases, more than one enteric pathogen being found in 5%–20%. An enteric pathogen was found in 30% of the healthy controls. Rotavirus, Shigella and Enterotoxigenic Escherichia coli were consistently very much more prevalent in the cases than in the controls. Mixed infections were detected approximately three times more frequently in the cases than in the controls, and diarrhoea of undetermined aetiology was highest among children aged less than six months.

Research into the aetiology of diarrhoea in Kenya reveals similar variation. An examination of 382 stool specimens collected by random sampling in the course of a house-to-house survey in Machakos District showed no significant difference in the rates of isolation of enteropathogens between the specimens from children with and without diarrhoea (Leeuwenburg *et al.* 1984), while an investigation in the Kenyatta Hospital reported 16% of the children admitted to hospital for diarrhoea to have enteropathogenic E. coli, Shigellae or Salmonellae (Kalya & Oduori 1972). In the Kiambu District of Kenya, 71% of diarrhoea specimens from children below 60 months had mixed infections, involving Escherichia coli, Shigella, Salmonella, Campylobacter, Rotavirus and parasites including Cryptosporidium (Chunge *et al.* 1989, Simwa *et al.* 1989).

Seasonal variations in the occurrence of acute diarrhoeal disease are reported in different parts of the developing world. Viral illnesses are observed all the year round in tropical climates, while bacterial and possibly parasitic diarrhoeas are more common in the warmer, rainy season (Barrel and Rowland 1979a, 1979b, Black *et al.* 1982a, Broek *et al.* 1993, Echeverria *et al.* 1989, Guerrant *et al.* 1983, Guerrant *et al.* 1986, Mertens *et al.* 1990a, 1990c, Pinfold 1990a, 1990b, Pinfold *et al.* 1991).

2.3. Water supply, sanitation and diarrhoea

Most assessments of the impact of water and sanitation on the health of children have focused on the rate of diarrhoea, nutritional status or mortality. In a review of the effects of improved water supply and sanitation on diarrhoea morbidity, the median reduction in diarrhoea morbidity achieved by improved water supply and sanitation in all the 49 reports reviewed studies was 22%, ranging from 0% to 100% (Esrey and al. 1985, Esrey & Habicht 1986, Esrey and al. 1991).

2.3.1. Combined improvement of water and sanitation

Diarrhoea attack rates in urban Bangladesh were found to be very high, with an increased risk associated with an income below the median, but no association with water or sanitation facilities was found (Stanton & Clemens 1987), although a previous study reported an average reduction of 30% in diarrhoea in Bangladesh to be associated with improved water and sanitation conditions (Rahaman *et al.* 1982). A combined intervention involving improved water supplies, installation of water-sealed double-pit latrines in the households and education related to water use and sanitation practices in one area of Bangladesh led to 25% fewer episodes of diarrhoea in children aged 6–60 months (Aziz *et al.* 1990). In another area a decrease of 40% in the incidence of diarrhoea in children aged 6–23 months was achieved after intervention in the form of an augmented water supply and health education. The latter included removal of the children's faeces from the yard and maternal handwashing before handling food and after her own or a child's defecation (Alam *et al.* 1989b).

When the combined effect of water and sanitation on diarrhoea morbidity was studied in Colombia, an average reduction of 30 % in diarrhoea was associated with improved water and sanitation conditions (Koopman 1978). Similarly, improvements of the water supply and excreta disposal in an urban area of Brazil reduced the estimated prevalence of diarrhoea by 45% and 44% respectively (Gross *et al.* 1989).

In Nigeria no clear indication of a reduction in the prevalence of diarrhoea was observed after water supply and sanitation intervention, as reductions occurred in some age groups in certain control villages as well as in the intervention areas. No age-specific or seasonal impacts were found (Huttly *et al.* 1990).

In two rural case-control studies, one in Malawi (children < 5 years) and another in the Philippines (children < 2 years), better water supplies and disposal of the family excreta led to 20% fewer cases of diarrhoea in children, but the results did not reach statistical significance (Baltazar *et al.* 1988, Young & Briscoe 1987).

Research results on the combined effects of water supplies and sanitation on diarrhoea morbidity thus vary between countries and between geographical areas inside the same country. There are many possible vehicles for the transmission of diarrhoea, such as contaminated water, food, hands and soil, and human and animal excreta. The density of population, the age distribution of the children, climatic variations, socioeconomic structure and differences in research methodology contribute to the difficulty of comparing the results reported. Recent case-control studies suggest that combined water supply and sanitation improvement may reduce diarrhoea in small children (Baltazar *et al.* 1988, Young & Briscoe 1987).

2.3.2. Water quality and source of water

In many parts of the developing world water quality monitored in terms of faecal contamination at source shows seasonal variations, which differ with reference to the type of water source (Barrel and Rowland 1979b, Blum *et al.* 1987, Mertens *et al.* 1990c, Moe *et al.* 1991, Laike 1992, Lehmusluoto 1987, Sandiford *et al.* 1989, Tomkins *et al.* 1978, Wright 1982). Furthermore, uncontaminated source water may become polluted during inappropriate transportation and storage. Water stored at home has been found to be more contaminated than water at source (Blum *et al.* 1990, Laike 1992, Lehmusluoto 1987, Mertens *et al.* 1990c, Molbak *et al.* 1989, Sandiford *et al.* 1989). In Bangladesh and Nigeria, a larger proportion of home storage water samples were contaminated during the rainy season than during the dry season (Henry *et al.* 1990b, Huttly *et al.* 1990).

Several authors have measured the faecal contamination of water at source when studying diarrhoea morbidity (Agarwal *et al.* 1986, Gorter *et al.* 1991, Henry & Rahim 1990, Moe *et al.* 1991, Ryder *et al.* 1985), and in a few cases contamination was examined both at source and at home (Mertens *et al.* 1990b, 1990c, Young & Briscoe 1987). Some of these authors could not demonstrate the significance of polluted water for diarrhoea morbidity independently of other variables (Agarwal *et al.* 1986, Gorter *et al.* 1991, Henry & Rahim 1990, Mertens *et al.* 1990b, Ryder *et al.* 1985), while one found a significantly higher diarrhoea attack rate only among those using grossly contaminated drinking water (Moe *et al.* 1991). In Malawi the quality of water at home was primarily dependent on the quality at source, and a good quality water source and use of a latrine together reduced diarrhoea slightly during the hot rainy season (Young & Briscoe 1987).

Reports from Nigeria and Sri Lanka could not verify the effect of boiling of the water on diarrhoea in children (Huttly *et al.* 1990, Mertens 1990b), which is an argument against a close association of water contamination with the rate of diarrhoea in those environments. A similar finding is reported from the Gambia, where no difference was found in the level of contamination of the water consumed between disease-free children and children with a high prevalence of diarrhoea in an urban area (Lloyd-Evans *et al.* 1984). A recent Malaysian survey has shown, however, that regular boiling of the water reduces the risk of diarrhoea, but the authors observed that socioeconomic, cultural and behavioural patterns were linked to regular boiling of the water (Lonergan & Vansickle 1991).

Several reports showing the benefit gained from an improved water source with respect to diarrhoeal morbidity have studied piped water in or near the house. The introduction of deep well tap water was found in China to be associated with a reduction of 38% in the incidence of acute diarrhoea in all age groups (Wang *et al.* 1989), while in Egypt, a lower incidence of infant diarrhoea was found when tap water was used for cooking, but the source of drinking water, tap vs. well, had no effect on the incidence of infant diarrhoea (Wright *et al.* 1991). In a South African peri-urban and urban area, children not having inside tap water had more than a threefold occurrence of diarrhoea (OR 3.3.) as compared with those having inside tap water (Schirnding *et al.* 1991). In Zaire the median diarrhoea incidence of children under 4 years of age was significantly lower (11%) in villages with piped water than in villages without a piped water supply (Tonglet *et al.* 1992).

The improvement of protection against pollution in water sources other than piped water has shown little or no influence on diarrhoea morbidity, or only a limited impact in certain age groups (Gorter *et al.* 1991, Esrey *et al.* 1988, Henry *et al.* 1990a, Huttly *et al.* 1990, Ryder *et al.* 1985). Three recent reports, however, mention a substantial benefit to be gained from improvement of water sources. Water drawn from unprotected sources increased the risk of diarrhoea in Malaysia (Lonergan & Vansickle 1991) and in Thailand (Thongkrajai *et al.* 1990), while Sri Lanka children in households drawing their drinking water from hand pumps were found to suffer 46% fewer episodes of diarrhoea and children of users of protected traditional wells 35% fewer episodes than children of users of unprotected traditional sources (Mertens *et al.* 1990b).

2.3.3. Water quantity and distance from water source

The significance of the quantity of water used and the availability of water has emerged as a target for investigation when the role of water quality in the aetiology of diarrhoea in children has remained unclear. In Sri Lanka and Nicaragua the quantity of water used was not found to be dependent on the type of source except for an in-house or yard source (Mertens *et al.* 1990b, Sandiford *et al.* 1990). The distance to the water source appeared to be the most important determinant of the quantity of water used per person per day. In Nicaragua a decrease in the distance from the water source from 1 km to 10 m was associated with an increase in per capita water consumption of 20% (Sandiford *et al.* 1990).

In Ethiopia and Panama an increased amount of water used was associated with less diarrhoea among children under five years of age (Freij & Wall 1977, Ryder at al. 1985). A reduction in the water collection journey in Mozambique led to an increase in the average daily water consumption, but the samples were too small to detect any reduction on diarrhoea rates (Cairncross & Cliff 1987). In Nicaragua, however, a distance of over 500 m from the household to the water source increased the occurrence of diarrhoea in children by 34% by comparison with children of households with their own water source (Gorter *et al.* 1991). Similarly, the median diarrhoea incidence per two weeks in Zaire was halved in children who lived in households located less than five minutes' walk from the public standpipe (Tonglet *et al.* 1992) and a daily water collection time of more than 2 hours was associated with a threefold increase in the risk of diarrhoea in Nigeria (Huttly *et al.* 1990).

2.3.4. Sanitation

In a review of the literature up to 1989 on the impact of sanitation on diarrhoeal morbidity, the median of the reduction noted in five reports was 35% (Esrey at al. 1991).

In a recent research from peri-urban and urban South Africa, not having a refuse receptacle and a flush toilet inside the house were both significant risk factors for diarrhoea in children under 5 years of age, with OR 3.3 and OR 2.5, respectively. Both remained independent risk factors in the logistic regression analysis when certain confounding variables such as tap water, electricity in the house, child's age <2 years/ 2–5 years, persons per room <2/ ≥ 2, monthly income, refrigerator, maternal education and problems with flies in the household were standardized (Schirnding *et al.* 1991). Similarly, ownership of a flush toilet was closely related to low diarrhoea morbidity in Malaysia (Lonergan & Vansickle 1991).

The possession of latrines showed no statistical relationship with infantile diarrhoea in rural Egypt (Wright *et al.* 1991), or child diarrhoea in Sri Lanka (Mertens *et al.* 1990b), Nigeria (Huttly *et al.* 1990) or Nicaragua (Gorter *et al.* 1991). Lesotho children less than 5 years of age in households with a latrine nevertheless had 24% fewer episodes of diarrhoea than children of the same age in households without a latrine. The impact of a latrine was greater in the households that used more water and practised better personal hygiene, and where the mother had a higher level of education or worked outside the home (Daniels *et al.* 1990).

Defecation by children out of doors rather than in a latrine was associated with a higher rate of diarrhoea in those under three years of age in Lima, Peru (Yeager *et al.* 1991). Similarly the presence of faeces in the compound was associated with a 48%

increase in diarrhoea morbidity in an urban area in Papua, New Guinea (Bukenya & Nwokolo 1991). A significant increase in diarrhoea among children (<3 years of age) was found in Kinshasa, Zaire, if the child's stool was not disposed of in a latrine (Dikassa *et al.* 1993).

The association of absence of a latrine in the household with frequent occurrence of diarrhoea in children was not constant in the above mentioned reports. On the other hand, a flush toilet and hygienic compound were reported to reduce the diarrhoea morbidity.

2.3.5. Hygiene

Enteric infections can be spread via contaminated hands, and hands can be decontaminated by washing with soap and water. Washing with water only removes a considerable but smaller proportion of the pathogens (Feachem 1984).

Several investigations in developing countries have focused on the influence of the mother's personal and domestic hygiene on diarrhoea in her children. In Bangladesh, a reduction of 35% in the Shigella diarrhoea attack rate was found after an intervention promoting handwashing (Khan 1982), while in an urban area in Thailand the mother's handwashing before eating and after defecation, together with the covering of food against flies, reduced the occurrence of diarrhoea significantly in children under five years of age (Vathanophas *et al.* 1986). An educational intervention in urban Bangladesh had a 26% protective efficacy on the diarrhoea attack rate among children 0–5 years of age in the intervention communities compared with control communities. A corresponding improvement in the mother's handwashing practices before preparing food was detected (Clemens & Stanton 1987). Similarly, rural Thai children aged 0–4 years whose mothers washed their hands before breastfeeding, served the food immediately after cooking it and warmed the food each time before a meal suffered from significantly less diarrhoea than children whose mothers did not practise these habits (Thongkrajai *et al.* 1990).

A cross-sectional baseline study in Nigeria showed rubbish in the household compound to be associated with a higher risk of diarrhoea (risk ratio, RR 1.3) (Huttly *et al.* 1987). Cleanliness of the kitchen and yard and "clean children" were significantly associated with low diarrhoea morbidity in Malaysia (Lonergan & Vansickle 1991). In the Philippines, the low indices of overall cleanliness and kitchen hygiene among low income families in metropolitan Manila were significantly associated with severe, hospitalized cases of diarrhoea in children below two years of age as compared with age-matched children from the same neighbourhoods. This excess risk persisted after controlling for tap water in the home/public tap, flush toilet/none, mother's education, occupation of the head of the household, nutritional indicators and feeding patterns (Baltazar *et al.* 1993). In Kinshasa, Zaire, accumulation of unburied solid waste in the compound carried a highly significant risk of diarrhoea in children under three years of age, and the same was found regarding maternal ignorance of the significance of poor hygiene for diarrhoea (Dikassa *et al.* 1993).

The impact of hygienic factors on diarrhoea of children emerges in research from many settings. Some of the hygienic habits are closely related to water, e.g. washing of the hands and cooking utensils, while others reflect social and environmental factors prevailing in the community, and the knowledge and experience possessed by the mother.

2.4. Methodological and interpretational problems in a case-control approach to the association between water supply and diarrhoea

Much attention has been devoted in recent years to the methodological issues involved in assessing the impact of improved water supplies and sanitation on health. It has been shown that quasi-experimental, cohort and cross-sectional studies of the impact of water supply and/or excreta disposal on diarrhoeal disease have encountered methodological problems which hamper the drawing of conclusions (Blum & Feachem 1983).

Quasi-experimental inquiries into the health impact of water and sanitation arrangements seldom have fully comparable control and treatment groups, and it is extremely difficult to adjust for this non-comparability by statistical methods (Cook & McAnany 1979). If comparison is made internally, within one area before and after intervention, there are secular trends, e.g. sudden, unexpected events which may violate the assumptions of comparability between the treatment and control groups (Blum & Feachem 1983). The required sample size is large, and the cost of the investigation is therefore high. Problems in defining the health indicator and failure to record facility usage are common, as is the consequent misclassification (Blum & Feachem 1983). In a validation test on the definition of diarrhoeal episodes for the purpose of community-based prospective surveillance, three or more loose stools within a 24-hour period or any number of loose stools containing blood proved to be the best definition of diarrhoea (Baqui *et al.* 1991). The reporting errors in a one-week diarrhoeal recall survey showed underestimation of severe diarrhoea by 20–22% and of less severe diarrhoea by 42–44% (Alam *et al.* 1989a). A further problem is that the allocation of communities to treatment and control groups is susceptible to political preference for some areas (Baltazar 1991, Briscoe *et al.* 1985, 1986).

Likewise, cohort studies suffer from many of the problems quoted above (Blum & Feachem 1983, Briscoe *et al.* 1985, 1986). The required sample size is large, the likelihood of misclassification is similar, but the ethical dilemmas are reduced because of the observational nature of the approach.

A cross-sectional study has <u>similar</u> size requirements to the two previously mentioned types and the problems of misclassification are also similar (Blum & Feachem 1983, Briscoe *et al.* 1985, Forsberg *et al.* 1993).

When water supply and sanitation programmes are to be assessed by measuring their impact on health, it would be useful to achieve rapid results at a relatively low cost. The case-control approach is promising as a rapid, inexpensive method of making such assessments (Baltazar *et al.* 1988, Baltazar 1991, Briscoe *et al.* 1985, 1986). It has been used to evaluate the combined impact of water supply and sanitation in Malawi (Young & Briscoe 1987) and the Philippines (Baltazar *et al.* 1988, Baltazar *et al.* 1993), the impact of sanitation only in Lesotho (Daniels *et al.* 1990), and the impact of water supply only in Sri Lanka (Mertens *et al.* 1990b) and Nicaragua (Gorter *et al.* 1991).

The case-control method has several advantages. Above all, it requires a smaller sample size, and is thus more efficient (Baltazar 1991, Briscoe *et al.* 1985, 1986). Due to this smaller sample size, the observation period can be adjusted for seasonal variations in diarrhoea in order to depict the influence of improved water supply and sanitation on the peak in bacterial diarrhoea, which occurs during the warm rainy season (Barrel and Rowland 1979b, Black *et al.* 1982a, Guerrant *et al.* 1983, Guerrant *et al.* 1986, Mertens *et al.* 1990a, Pinfold 1990b, Pinfold *et al.* 1991) and is therefore more susceptible to improvements in water supply (Baltazar 1991, Zoysa & Feachem 1985). With a case-control design, in which only children reporting to the clinic with diarrhoea are included as cases, the proportion of clinically significant diarrhoea is high, whereas with other study designs, which rely on periodic surveillance for the detection of cases, mild cases of diarrhoea of doubtful public health significance are included and the time lag between recalls influences disease reporting (Alam *et al.* 1989a, Baltazar 1991, Forsberg *et al.* 1993)). The case-control method has also the advantage of involving only one single round of data collection, hence misclassification biases are easier to detect. Data collection needs to be initiated only after the improved system is functioning adequately (Baltazar 1991, Briscoe *et al.* 1985, 1986), and the method does not run into the ethical problems of quasi-experimental designs (Baltazar 1991, Briscoe *et al.* 1985, 1986).

The case-control method naturally has its shortcomings. It is impossible to assess the impact on more than one outcome measure (Baltazar 1991, Briscoe *et al.* 1985, 1986, 1988), avoidance of sampling error requires careful planning of sampling procedures (Baltazar 1991, Briscoe *et al.* 1985, 1986, 1988), and there is still a considerable danger of misclassification and selection bias (Baltazar 1991, Briscoe *et al.* 1985, 1986, Cole 1979), which can be more serious in developing than in developed countries (Casley & Lury 1981, Stanton *et al.* 1987). Distortion is also possible if the effect of the factor under investigation is mixed with those of confounding variables (Briscoe *et al.* 1985, 1986), although the latter proved to be of minor importance for surveys conducted in Malawi and the Philippines (Baltazar 1991, Baltazar *et al.* 1988, Briscoe *et al.* 1988, Young & Briscoe 1987).

2.4.1. Correct classification of diarrhoea and control children

Possible misclassification of disease in a clinic-based survey is dependent on the symptomatology as reported by the mother and confirmed by the health personnel. It is reasonable to assume that more severe cases of diarrhoea are brought to a clinic, whereas mild cases are treated at home. The health personnel, especially in crowded clinics in developing countries, rely to a great extent on the information given by the mother about the child's symptoms. Diagnoses of diarrhoea based on a maternal report of frequent loose or liquid stools had a sensitivity of 95–97% and specificity of 80% in Cebu, Philippines (Kalter *et al.* 1991). Both in the Philippines and Malawi, experiences in surveys where the disease status of potentially eligible children was ascertained by clinically trained project nurses suggested that, provided the level of training was relatively high, selection of the cases and controls by the examining clinician would not introduce serious misclassification errors (Briscoe *et al.* 1988). Where the personnel providing clinical services were less well trained, however, it was admitted that the recruitment of cases and controls would require supervision from additional project staff (Briscoe *et al.* 1988).

2.4.2. Correct classification of water source used

The type of water source used does not seem to carry with it cultural taboos, and therefore no serious misclassification should not arise. The utilization of a source of water depends on the availability of water at it, the mechanical functioning of the supply and the physical quality of the water (Kiyu & Hardin 1992). In line with this finding, a seasonal variation in the utilization of different water sources was recorded in Sri Lanka, related to the availability of water at the nearest source during the dry and rainy seasons respectively (Mertens *et al.* 1990c).

In the surveys carried out in Malawi and the Philippines the water sources were classified by means of an interview and by inspection in the home by the project data collector, and the authors assume the danger of misclassification of the type of water source to be minimal (Baltazar *et al.* 1988, Young & Briscoe 1987). Water source information was collected in Nicaragua by means of an interview at home, and the repeatability score for the repeated interviews was excellent. No inspection of the type of water source was performed, however (Sandiford *et al.* 1990), so that the correctness of the classification still depended on the information given by the mother.

In a large survey conducted in Sri Lanka, 23% of the mothers who claimed at the clinic to be using an unimproved water source, reported at home that they were using an improved water source, while conversely 22% of the mothers claiming at the clinic to be using an improved water source reported at home that they were using an unimproved one. The relative rate of diarrhoea derived from the data collected at the clinic was 0.84 and that derived from the data collected at home 0.92. When the relative rate of diarrhoea was calculated on the basis of the clinic interview data, but separately for the children for whom there was agreement between the exposure data given at the clinic and at home and for those for whom there was disagreement, the respective figures were 0.82 and 0.86. The authors conclude that the water source data obtained from the clinic interview were more appropriate and that the differences in the exposure data most likely reflected real changes in water source between the two interviews (Mertens *et al.* 1990a).

2.4.3. Correct information on sanitation and hygienic behaviour

Information on sanitary practices collected from mothers at clinics did not correlate well with observed sanitary practices in Bangladesh (Stanton *et al.* 1987). In a recent case-control study in Lesotho, in which information on exposure to improved sanitation facilities collected by interview at a clinic was verified with random home visit interviews and observations of case and control households, the sensitivity of the data on latrine ownership was 0.97 and the specificity 0.97, suggesting that the household data were correct (Daniels *et al.* 1990). A survey in the Philippines used interviews at home and observation of the immediate vicinity of the household to assess the use made of excreta disposal facilities and the appropriateness of hygiene practices (Baltazar *et al.* 1988). Latrine utilization data collected in Malawi relied on information given by the mother at a home visit and on inspection of the latrine (Young & Briscoe 1987). The same authors later concluded that sanitation practices are a sensitive area in which the likelihood of correct answers at the clinic would always be open to question. The opinion was that no definitive conclusion can be reached concerning the validity of exposure data collected at clinics versus data collected in the home and that there is a need for the development and validation of instruments measuring hygienic behaviour (Briscoe *et al.* 1988). The difficulty of data collection on sanitary practices is also shown in a report from Burkina Fasso, where poor agreement (68%) was found between the answers to a questionnaire regarding the child's place of defecation and direct observations at home visits (Curtis *et al.* 1993).

2.4.4. Summary of methodological aspects

The supervision that can be maintained over selection bias or misclassification of cases and controls depends on the sampling procedures. Children brought to a clinic with diarrhoea as their primary complaint are eligible as cases even though they may also have other water and sanitation-related diseases as secondary complaints, while the children eligible for the control group must have a disease of similar severity to diarrhoea but not related to water or sanitation, e.g. an acute respiratory disease. Cases can become cases again and controls can become controls again provided the second visit is not for the same episode. Controls who later become cases and cases who later become controls are also permitted (Rodrigues & Kirkwood 1990), but if the time of recruitment is relatively short re-enrolment will be extremely rare (Briscoe *et al.* 1985, 1986, Young & Briscoe 1987). If the availability and utilization of an improved water supply and sanitation are correlated with distance from the clinic, this can affect sampling (Briscoe *et al.* 1985, 1986). The effect of distance from the clinic on reporting of the case and control diseases should be equal if the propensity to report a disease depends on the severity of that disease and the two diseases are of similar severity. It is only when there is a simultaneous major differential effect of distance on disease reporting, e.g. a great proportion of patients in the near zone served with improved water and sanitation and a very high correlation between distance from the clinic and the level of water services, that large biases will be introduced into the estimated odds ratio (Briscoe *et al.* 1985, 1986). The effect of possible selection bias due to socio-economic status is minimized by selecting controls from among children suffering from a disease of similar severity, by choosing several different areas for data collection and by including all the health service points serving the area. The potential confounding effect of socio-economic status has to be considered in the analysis stage even when the minimization of confounding factors has been taken into account during the design (Briscoe et al. 1985, 1986).

In order to obtain the ideal setting for a case-control study of the impact of water supply and sanitation on diarrhoea, it is desirable that there should be a variety of water supply categories in the population and that no one category should be used by only a small proportion of the population. It is also desirable to include several geographically distinct areas in order to control the exposure and confounding factors better. Recruitment should ideally be carried out at all of the health service facilities in the community. As a prior condition it is necessary that the improved water and sanitation services should be satisfactorily operated and that they should be used. The clinical and interviewing personnel should be experienced and trained, and cooperation from the staff of the health facilities and from the communities ensured (Baltazar 1991, Briscoe *et al.* 1985, 1986, 1988).

3. AIM OF THE RESEARCH

The aim of this research was to examine the occurrence of acute diarrhoea in children under five years of age among users of an unimproved water source (river, lake, pond, dam, pool, unprotected spring) and users of an improved water source (borehole, shallow well with hand pump, protected spring, roof catchment, tap water). The hypothesis was that the children of families who use an improved water source have less diarrhoea than those of families using an unimproved water source, thus the improvement of water sources would be visible in the form of a reduction in diarrhoea in children (see definitions of water sources on page 6 and Appendix 4, figures 1, 2 and 3).

The relation of the occurrence of diarrhoea to the quantity of water used per person in the household and distance from the water source was also assessed.

Other variables not directly connected with the water supply, such as education of the mother, number of children below 15 years, ownership and use of a latrine, washing of the hands before meals and enterobacterial contamination of the hands of the child or mother were included among the parameters examined, being possible factors associated with acute diarrhoea morbidity in children.

In addition, the degree of faecal coliform contamination in unprotected springs and improved water sources was examined during the dry and rainy seasons, together with enterobacterial contamination of the water stored at home.

4. METHODS AND MATERIAL

4.1. Area studied

This case-control study was conducted in the Western Province of Kenya with the consent of the Ministry of Health of Kenya and FINNIDA. The Kenya-Finland Primary Health Care Programme and the Kenya-Finland Western Province Water Supply Project, both bilateral development projects organized by the Kenyan authorities and FINNIDA, collaborated in the implementation of the fieldwork for this research. The areas within a radius of 5 km of the Health Centres of Navakholo, Matete, Ipali, Sio Port, Kabuchai and Hamisi were included. These areas together had an approximate population of 160,000 (Appendix I, Maps 1, 2, 3, 4 and 5) and a mean density of population in the areas of the study was 340 persons per sq.km. All the areas are rural, depending economically mainly on small-scale farming, although migratory work in urban centres outside the province is common.

The water sources improved by the bilateral project are numbered by type and location. The distribution of water sources built by the project within a radius of 5 km of the Health Centres of Navakholo (28 protected springs, 15 shallow wells and 9 boreholes), Matete (8 protected springs, 25 shallow wells and 11 boreholes) and Kabuchai (18 protected springs, 17 shallow wells and 30 boreholes) is shown in Appendix I, maps 2, 3, 4 and 5. In the area of Sio Port all 19 water sources improved by the project were boreholes with hand pumps. Two of the Health Centres, Ipali and Hamisi, lie outside the scope of the Kenya-Finland Western Province Water Supply Project and the improved water sources in these areas are almost exclusively protected springs.

All the Health Centres were inside of the geographical area covered by the Kenya-Finland Primary Health Care Programme. The author had an established working relation with the Health Centre staff during the fieldwork period.

4.2. Timing of data collection

The data on the patients were collected at the six Health Centres during the period 18.3. – 16.4.1991. The heavy rains were delayed in 1991 and only last two weeks of data collection occurred during that season. The area of Sio Port Health Centre, adjacent to Lake Victoria, remained dry before the rains, but the other areas have some rain all year round and had at least a shower each afternoon. The home visits and cultivations of water samples from the households took place between 20.3.1991 and 30.4.1991.

The samples for the cultivation of faecal coliforms from the water sources were collected between 22.2.1991 and 11.3.1991 for the dry season and between 25.4.1991 and 23.5.1991 for the rainy season.

4.3. Sample size

The sample comprises 1129 patients, 502 children with acute diarrhoea (males 51%) and 627 control children (males 53%) with acute respiratory infection (ARI).

Visits were made to the homes of 98 children with acute diarrhoea and 113 control children with the intention of checking the patient history data given at the health centre and taking a sample of the water stored at home for cultivation.

Data on one control patient and the corresponding home visit (not included in the above figures) were withdrawn from the material because of uncertainty about the identification number of the patient.

4.4. Selection of cases and controls

A case was defined as a child under five years of age who was brought to the health centre with acute diarrhoea during the period of data collection and whose home was within the radius of 5 km of the health centre. Diarrhoea (3 or more loose stools during the preceding 24 hours) was reported by the mother and verified by an attending nurse. If the mother indicated other complaints in the child besides diarrhoea the child was not included in the series. All the cases seen at the clinics during the recruitment period that satisfied this definition were recorded. Although re-entry of a case or control was permitted, none occurred during the four weeks of data collection.

A control was defined as a child aged under five years who was brought to the health centre with an acute respiratory disease, i.e. influenza, pneumonia, rhinitis, laryngitis, acute cough with fever, but without diarrhoea during the preceding 24 hours, and whose home was within a radius of 5 km of the health centre. All the children seen at the health centre during the data collection period who satisfied these criteria were recorded as controls.

4.5. Collection of patient history data

A questionnaire for the collection of patient data was designed, tested at two health centres, and revised prior to the study by the author with the assistance of local Kenyan health workers and advisers attached to both programmes.

The questionnaire was filled in by a community nurse and a public health technician at each health centre, both having an established working relation with the community and trained for this task. Running number diaries were kept at each centre for the cases and controls separately. Patient data sheets were collected daily from five of the health centres and once a week from Sio Port Health Centre. The questionnaire (appendix II) provides information on the dwelling place, age, sex, height, weight and feeding of the child, distance from the water source used, type of water source (borehole, shallow well, roof catchment or tap water, protected spring, unprotected spring, river, lake, dam, pool), quantity of water fetched daily for the household, type of water storage at home and frequency of cleaning it, ownership and type of latrine, use of the latrine by the mother and place of defecation of the child. Washing of the hands before meals was recorded for children aged 12 months or over and washing of the mother's hands before feeding an infant. The mother's age and education, number of members in the household and number of children alive under the age of 15 were also recorded.

4.6. Home visits

All the mothers attending four of the health centres were informed about the possibility of a home visit, and plans were made to visit every third diarrhoea patient and every third ARI patient at home for verification of the anamnestic data, checking of the type of water source, and taking of samples for enterobacterial cultivation from the household's water storage facility and from the right hand of the mother or the child.

However, rigorous sampling was not achieved due to delays in the home visits, refusals, failure to find the household or absence of the mother at the time of the visit. Due to the bias towards users of improved water sources among the households visited, only the bacteriological samples taken at home were used here. For the cultivation methodology, see 4.8 and 4.9.

4.7. Samples from water sources

All the water sources located nearer than 5 km from the health centre and improved by the water project were to be sampled during the dry and rainy seasons. However, the estimation of distance in the field was difficult and the contamination of the water with faecal coliforms was studied at 170 numbered improved water sources in the areas of the Navakholo, Kabuchai, Matete and Sio Port Health Centres in the dry season, and from 183 such sources in the same areas in the rainy season. 85 unprotected springs in the same areas were sampled by technicians for the cultivation of faecal coliforms during the dry season and 6 during the wet season. The small number of unprotected springs sampled during the rainy season was caused partly by the wet season itself (bad state of the roads), partly by the by lesser familiarity of technicians with the location of the unprotected springs and also by unforeseen circumstances in the daily routines of the technicians.

Surface water sources (river, lake, pool, dam) were not examined. Since the samples from the water sources were collected by technicians of the water project living in Kakamega, it was not possible to obtain information on sites from which families collected their surface water.

The membrane-filter method as described in Guidelines for Drinking Water Quality (World Health Organization 1985) was used for cultivation of faecal coliforms from samples taken from water sources. The samples were taken by Kenya-Finland Western Province Water Supply Project technicians and incubated and read in the water project's laboratory in Kakamega.

The criteria used for the contamination of water sources were the following:
clean = 0–5 colony forming units (c.f.u.) of faecal coliforms/100ml
moderately contaminated = 6–49 c.f.u. of faecal coliforms/100ml
heavily contaminated = ≥ 50 or more c.f.u. of faecal coliforms/100ml

4.8. Samples from water storage

A water specimen was obtained from 210 households during the home visits when the used source of water was also verified (see 4.6.).

Contamination of the water in the household's storage vessel as indicated by the growth of Enterobacteriaceae, was assessed using a commercial dip slide (HYGICULT E, Orion Diagnostica, Finland). Growth of 1 to 10 colonies/side of the slide (1 colony/sq.cm.) corresponds to ≥ 10 000 bacteria/ml, and > 10 colonies/side of the slide to over 10 000 bacteria/ml. Normal drinking water should have a negative cultivation, i.e. <10 000 bacteria/ml (Masher *et al.* 1989, Mossel *et al.* 1976). The slide was inoculated during the home visit by dipping it in the vessel of drinking water, after which it was replaced it in its sterile vial and coded. The coded vials were taken daily to the water laboratory of the Kenya Finland Western Province Water Supply Project in Kakamega and incubated at 37°C for 48 hours, after which the colonies were counted. The cultivation results with their code numbers were collected by the author, who then transferred the data to the computer.

The household water was considered contaminated if the growth of Enterobacteriaceae was > 10 000/ml, and safe for use as drinking water if it was 10 000/ml or less or no growth was detected.

4.9. Cultivation for Enterobacteriaceae on the hands

Cultivations for Enterobacteriaceae on the hands were performed using the same commercial slide as above for the children aged 12 months or more and the mothers of the infants at five health centres (Sio Port was excluded because of its long distance from the water laboratory) and at the home visits. Samples were taken by pressing all the fingers of the right hand against an agar slide for the growth of Enterobacteriaceae. The slides were then replaced in their sterile containers, coded with the patient identification number and collected daily for incubation and reading in the water laboratory in

Kakamega (Mossel *et al.* 1976). The results were grouped into negative and positive cases. A total of 1004 cultivations for Enterobacteriaceae on the hands were obtained from the health centre, 541 of them from mothers (234 in the diarrhoea group and 307 in the control group), and 463 from children (210 with diarrhoea and 253 with ARI).

During the 211 home visits 132 samples were obtained, 65 from mothers, 36 in the diarrhoea group and 29 in the control group, and 67 from the children, 31 with diarrhoea and 36 with ARI.

4.10. Statistical analysis

The data were coded and transferred to a personal computer by the author in Kenya using the software of Ashton Tate dBase IV. The patient's name and parents' names were excluded. The data were later transferred in the form of a sequential file from a diskette to the computer of Oulu University (IBM-ES/9121-260VF) and analyzed using the SAS software.

The analysis of the occurrence of diarrhoea in relation to a given variable was first performed by calculating the odds ratio (OR), 95% confidence interval (CI) and p-value (p) separately for each variable from a 2x2 contingency table (Mantel & Haenszel 1959, Cochran 1954). The SAS software for Cochran-Mantel-Haenszel's statistics was used.

Logistic regression analysis with the explanatory variable (use of unimproved water source) and selected potential confounders was used in order to obtain adjusted OR estimates for diarrhoea. There were 6 children from whom some of the data on the variables chosen for the logistic regression analysis were missing, and these children were excluded from the logistic regression analysis and from the confounder score analysis, yielding 1123 children in both.

In order to assess the joint effect of the variables other than the type of water source, a version of the confounder score approach was adopted (Miettinen 1976). A logistic regression model with the selected variables (excluding water source used) was fitted to predict the occurrence of diarrhoea in the children of the households using an improved water source. The fitted probability of diarrhoea based on the model coefficients and levels of the variables was then calculated for each subject in the whole material and separately for users of an improved water source and an unimproved water source. This fitted probability was used as a risk score to predict the likelihood of diarrhoea on the basis of all the other factors except the type of water source used by the household. Children having the same risk score, whether or not their household used an improved or an unimproved water source, are hence comparable with respect to the baseline risk as determined by the variables included in the model. Five equal strata were formed according to the risk scores in the group of children whose households used an improved water source, so that those in the first stratum, for example, had the lowest risk scores for diarrhoea and were mutually comparable except with respect to the type of water source used. By calculating the odds ratio in each stratum, the occurrence of diarrhoea could be related to the type of water source used. The pooled odds ratio and 95% CI were calculated from the stratum-specific odds ratios by the method of weighted least squares (Rothman K.J. 1986).

5. RESULTS

5.1. Characteristics of the population

5.1.1. Sex and age

There were slightly more males among both the diarrhoea children and the controls.

The mean age of the diarrhoea patients was 13.4 months and that of the control patients 15.8 months, and the corresponding median ages 11 months and 10 months. The distribution of the two groups by age are shown in Figure 1. The proportion of children aged 12–23 months was higher in the diarrhoea group than in the control group (34% versus 22%) and there were proportionally less children aged 2 years or more (14% versus 24%).

Since age is closely related to the diarrhoea morbidity, a stratification according to age (less than 12 months, 12 to 23 months, 24 months or more) was performed when analysing certain individual variables and in the logistic regression and confounder score analyses.

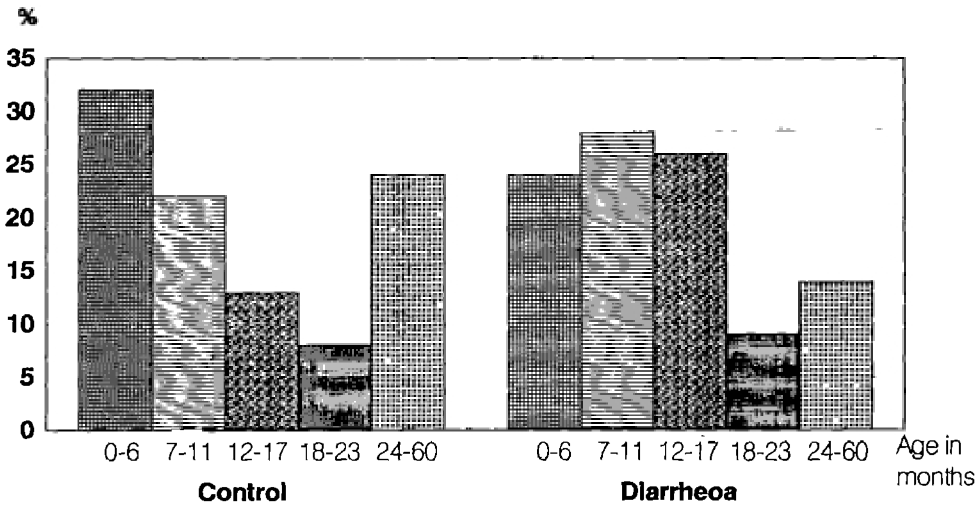

Fig. 1. Distribution of children by age (n. 1129).

5.1.2. Height and weight of the child

The intention was to include the height of the child in the characteristics to be studied, but this is not measured routinely in health centres in Kenya. Supervisory visits to the health centres showed, for example, that the measuring scale had not always been consistently installed. The data on height were therefore withdrawn.

Weighing of children, on the other hand, is a routine procedure in Kenyan health centres, and the weights of 1112 of the present children had been recorded. Moving-average values for weight by 3 month age groups (mean weight of children at a given age and in the previous and following months) for the diarrhoea and control children together with the reference curves used on the Kenyan Child Health Card (upper line = WHO 50th percentile for boys, lower line = WHO 3rd percentile for girls) are presented in Figure 2. No difference in weight was seen between the children in the diarrhoea group and control group during the first year of life. The mean weight remains inside the reference curves, but the weight gain slows down in both groups from six months of age, so that the weights of both groups approach the lower reference line on the Kenyan Child Health Card at the age of one year.

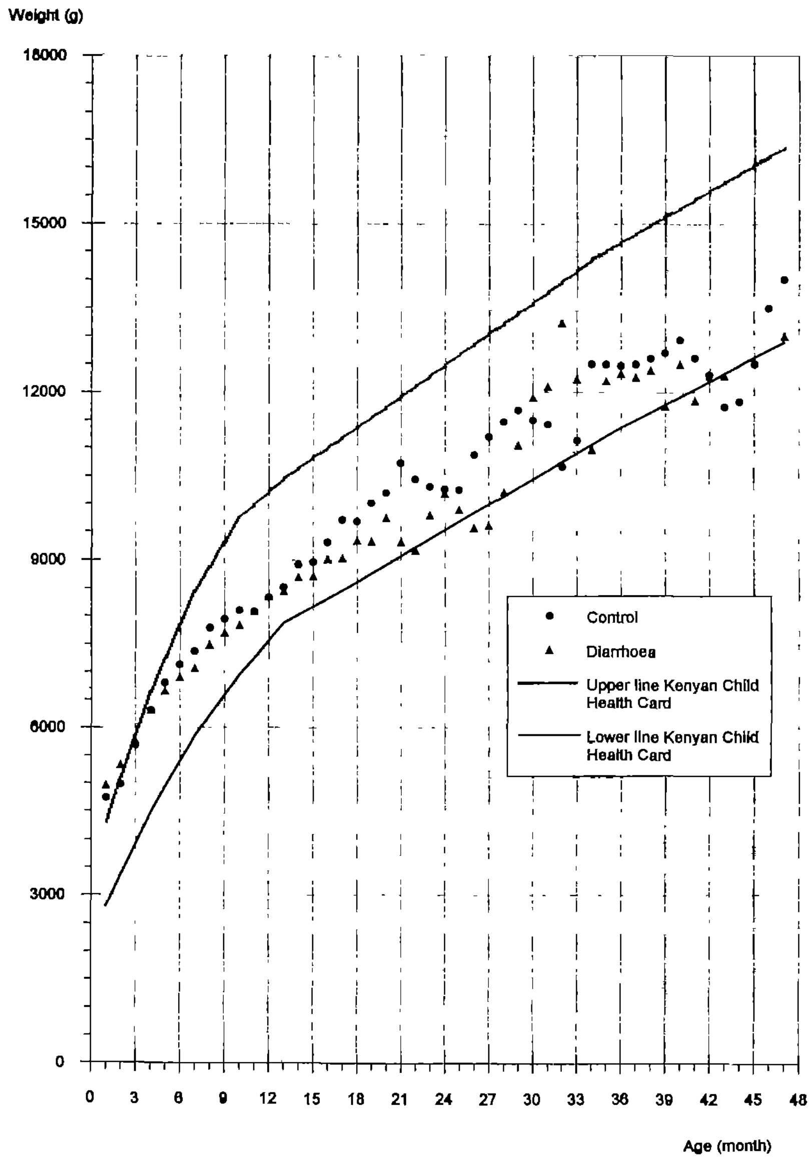

Fig. 2. Moving-average weights by 3-month age groups for the diarrhoea and control children (mean weight of children at a given age, previous and following months).

5.1.3. Age of the mother

The mean age of the mothers was 24.9 years in the diarrhoea group and 25.8 years in the control group, the median being 24 years in both groups. The range was from

15 years to 48 years in the diarrhoea group and from 15 years to 50 years in the control group. The age distributions in both groups are shown in Figure 3.

The proportion of mothers aged 20–29 years was higher in the diarrhoea group (66% to 60%) and the proportion of mothers aged 30 years or more was higher in the control group.

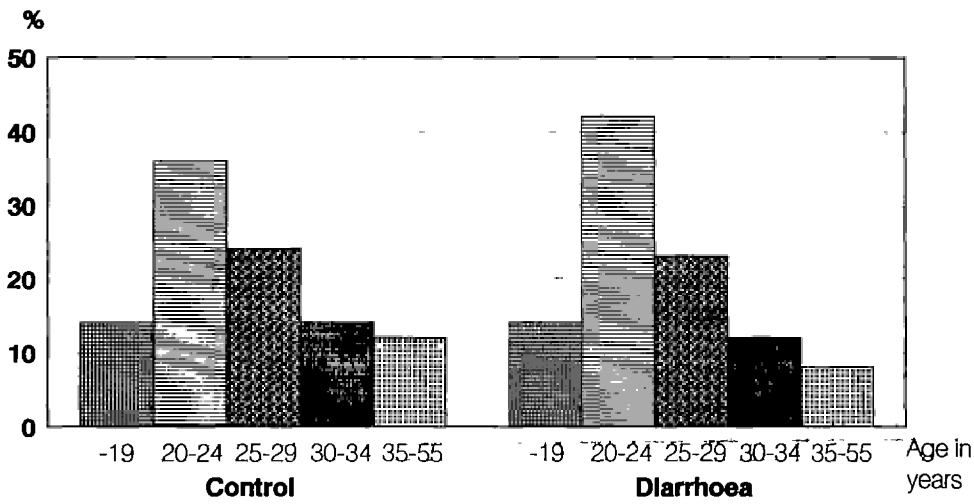

Fig. 3. Distribution of mothers by age.

The median age of the child by age of the mother is presented in Figure 4. The young mothers had sick children of similar age in both the diarrhoea and the control group, but the older mothers in the control group had older sick children than those of same age in the diarrhoea group.

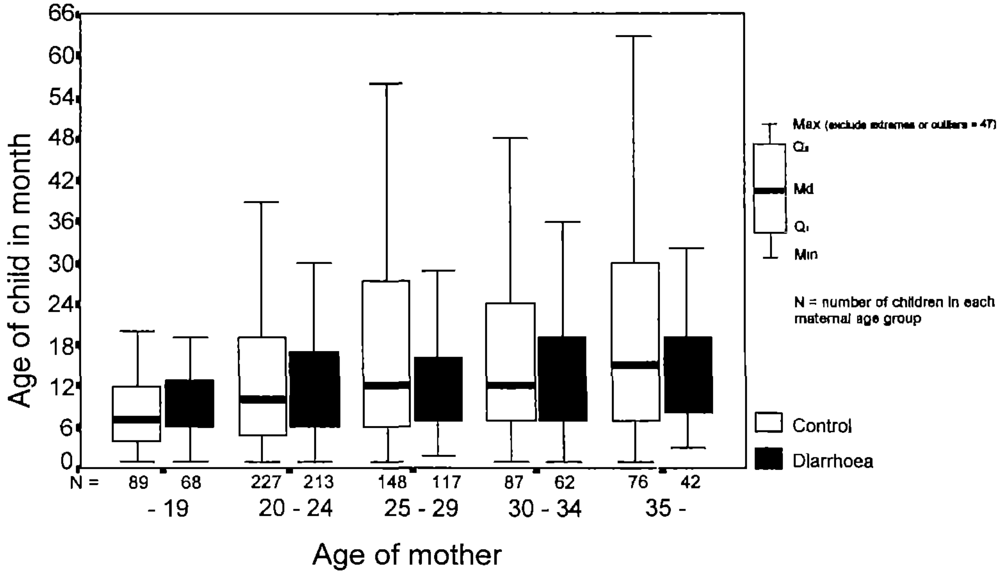

Fig. 4. Median age of the child by age of the mother (75% of the observations lie inside the rectangular figure between Q1 and Q3).

The mother's age was represented in the logistic regression analysis and confounder score analysis by three categories ≤19y, 20–29y, ≥30y.

5.1.4. Education of the mother

The education of the mother is presented in Table 2. The duration of primary school in Kenya was 8 years from independence until 1967, 7 years between 1967 and 1984 and has been 8 years since the educational reform of 1985, when secondary schooling was set at 4 years (Uitto 1989). 52% of the female population over 15 years of age in Western Province had no formal education in 1979 (Republic of Kenya 1981).

Table 2. Education of the mother as reported by herself.

Education of the mother	Diarrhoea patients % (n. 502)	Control patients % (n. 627)
Illiterate	12	16
Some primary school	44	38
Completed primary school	22	23
Some secondary school	14	14
Completed secondary school	8	9
No data on education	–	–
Total	100	100

– = less than 1.

There was a higher proportion of illiterate mothers in the control group than in the diarrhoea group (16% vs. 12%), especially among the older mothers (≥35 years), in whom illiteracy was 49% in the control group versus 31% in the diarrhoea group (47%), Figure 5.

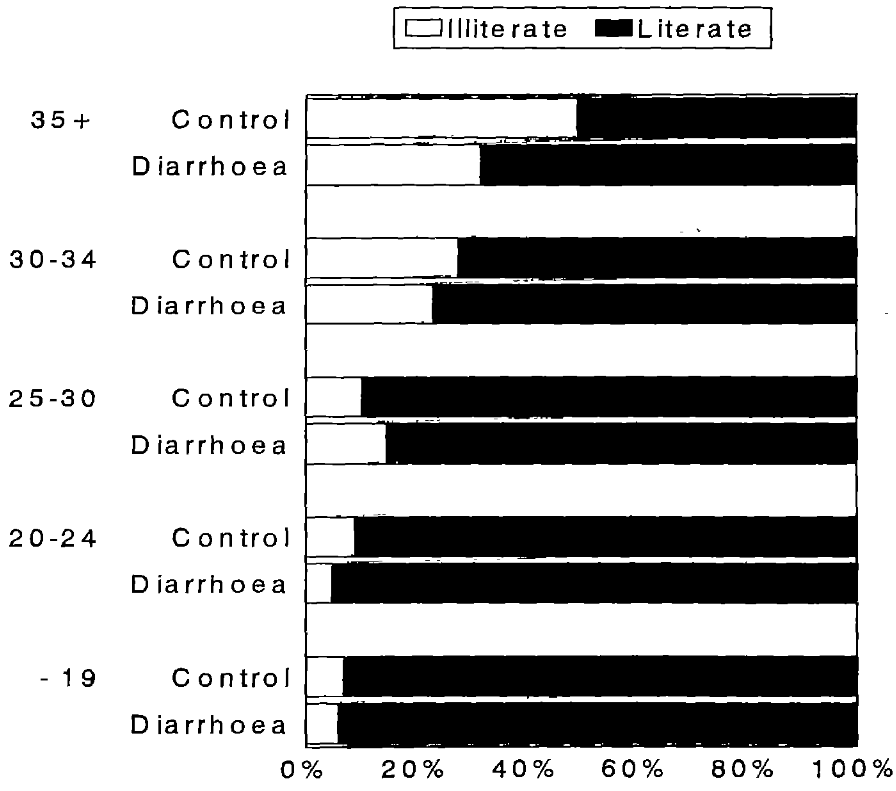

Fig. 5. Maternal illiteracy by age of the mother.

Due to the relatively small number of the illiterate mothers and their skewed age structure, the calculations in the logistic regression and confounder score analyses were based on a dichotomous variable: mothers who had not completed primary school vs. mothers who had completed at least primary school. Finishing of the primary school was chosen as an easily definable cutoff point, since "some primary school education" could mean either 1 or 6–7 years of schooling.

5.1.5. Number of children and household size

The mean number of children under 15 years of age of the mothers in the diarrhoea group was 2.7 and that in control group 2.9. 28% of the mothers in the diarrhoea group had only one child, compared with 25% in the control group, while 14% of the mothers had 5 or more children in the former case and 20% in the latter, Table 3.

Table 3. Distribution of mothers by number of children (<15y).

Number of children	Diarrhoea group	Control group
1	139	156
2	123	143
3	86	114
4	86	88
≥5	83	121
no data	2	5

The median numbers of children in the diarrhoea and control group families by the age of the mother are shown in Figure 6.

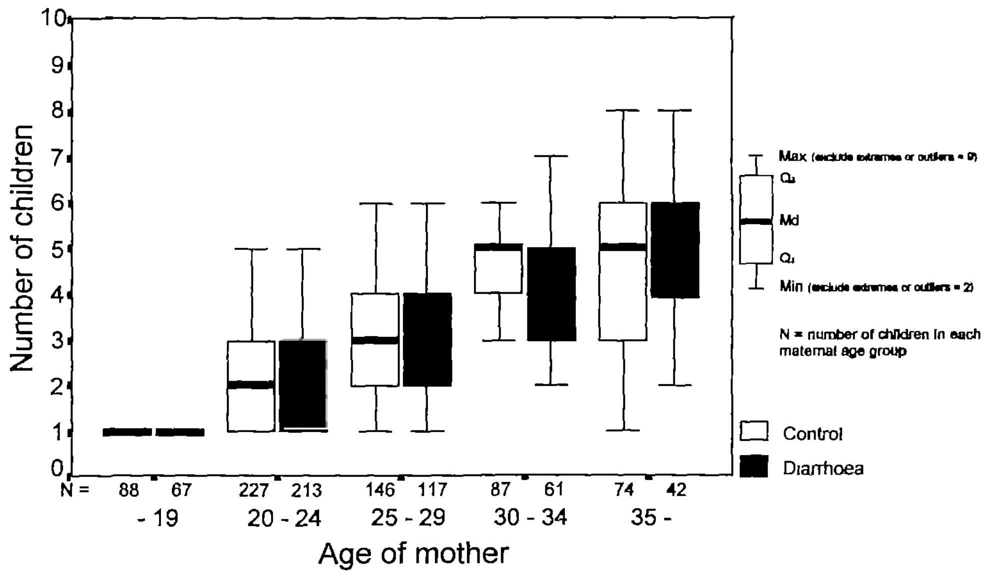

Fig. 6. Median number of children (< 15y) in the diarrhoea and control groups by age of the mother (75% of the observations lie inside the rectangular figure between Q1 and Q3).

The number of children was represented in the logistic regression and confounder score analyses by the categories 1, 2–3, ≥ 4.

The number of persons in the household depends mainly on the number of children under 15 years of age. The father of the child may not always be included in the household members, since migratory work outside the area is common and the father may be present only during leaves. On the other hand, extended family members living with the family and eating from the same pot may be included. The distribution of household size in both groups is shown in Figure 7.

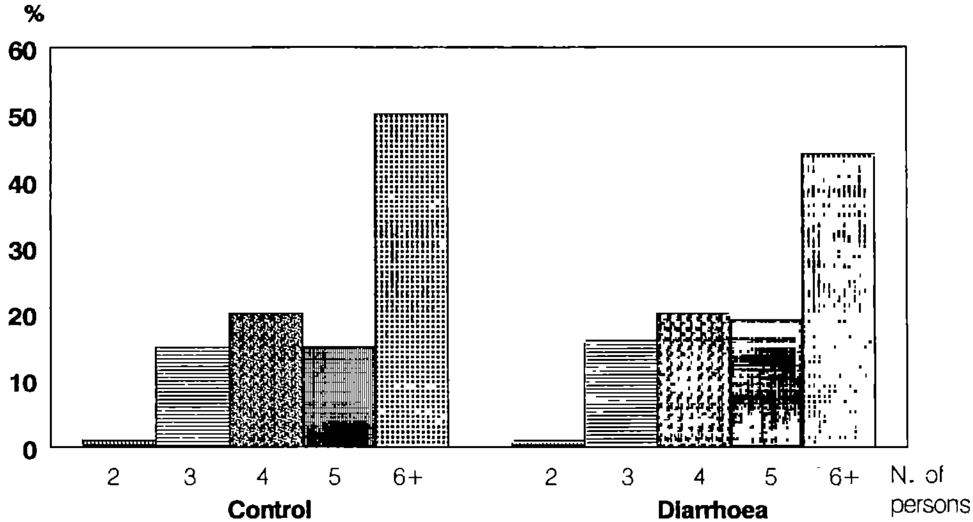

Fig. 7. Distribution of households by number of members.

5.1.6. Feeding of the child

The percentages of children exclusively breast-fed, receiving breast feeding and weaning food (semi-solid food such as porridge prepared for infants and children during the weaning period) and fed on the solid food eaten by the adult family members are presented by age group in Figures 8 and 9.

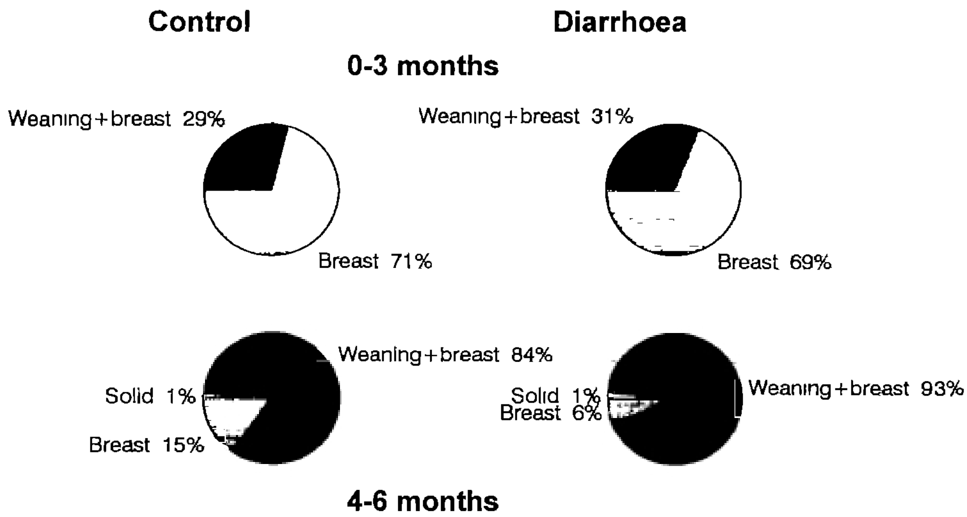

Fig. 8. Feeding practices among diarrhoea and control infants aged <4 months and 4 to 6 months.

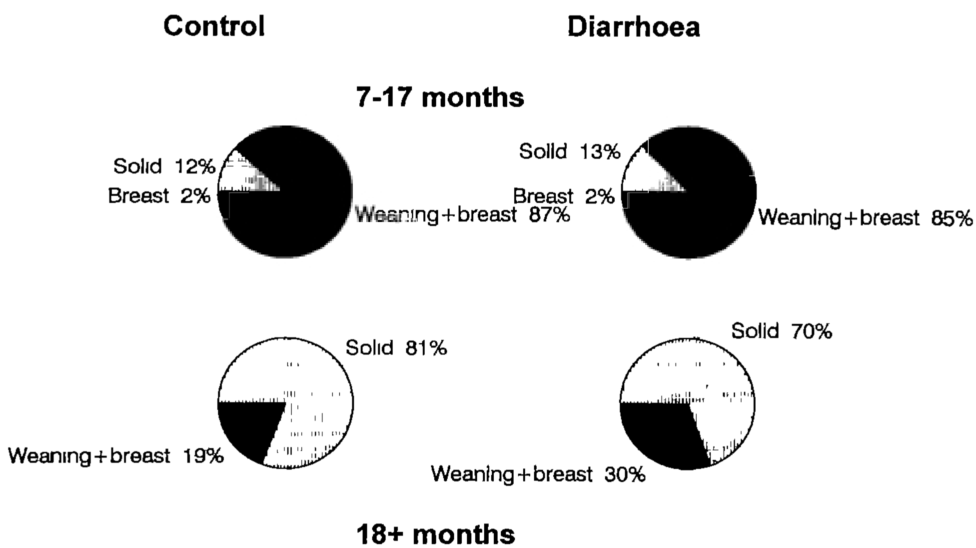

Fig. 9. Feeding practices among diarrhoea and control infants and children aged 7 to 17 months and aged 18 months or more.

Weaning had begun early in a small percentage of the children, by the age of 3–4 months. The age distributions of the breast-fed children and weanlings in both groups are shown in Tables 4 and 5. Out of the children on solid food as eaten by adult family members, 96% in the diarrhoea group (n. 113) and 97% in the control group (n. 191) were aged ≥12 months.

Table 4. Exclusively breast-fed infants by age group.

Age group	Diarrhoea group		Control group	
	n.	%	n.	%
0–3 months	27	73	67	77
4–6 months	5	14	16	19
7–11 months	4	11	3	3
≥ 12 months	1	3	1	1
total	37	100	87	100

Table 5. Children on weaning food by age group.

Age group	Diarrhoea group		Control group	
	n.	%	n.	%
0–3 months	12	4	27	8
4–6 months	77	22	90	26
7–11 months	131	37	130	37
≥ 12 months	131	37	102	29
total	351	100	349	100

5.1.7. Other variables

The distributions of the other variables among the diarrhoea and control children are shown in Table 6.

Table 6. Distributions of selected variables in the diarrhoea and control groups.

Variable	Diarrhoea group (n. 502) %	Control group (n. 627) %
Water storage vessel		
– clay pot	93	93
– jerry can	6	5
– other	1	2
– no data	0	–
Cleaning of water storage vessel		
– daily	24	20
– weekly	74	79
– less frequently	1	–
– no data	1	1
Latrine in the household		
– pit latrine	95	95
– VIP latrine	–	–
– flush toilet	–	–
– no latrine	5	5
– no data	–	–
Mother uses latrine	93	92
Child's defecation place		
– latrine	4	8
– behind the house or in the garden	26	28
– other	70	63
– no data	–	–
Mother washes her hands befor feeding the infant (< 12m)	13	14
Child's hands (1–5y) washed before meals	70	86
Mother's hand, negative cultivation	66	61
Child's hand, negative cultivation	70	72

– = less than 1

5.2. Use of improved and unimproved water sources and diarrhoea

112 protected springs, shallow wells with hand pumps and boreholes built or improved by the bilateral water project were recorded as being used by 212 households of children belonging to the present population, in addition to which there were 409 users of protected springs, shallow wells or boreholes built or improved by the people themselves or other agencies, 38 users of piped water schemes and 5 users of roof catchment of rainwater. The rest of the households used an unimproved water source.

The proportion of users of improved water sources was somewhat higher in the control group than in the diarrhoea group (61% vs. 56%), Table 7.

Table 7. Drinking water source.

Water source	Diarrhoea group n.		Control group n.	
Improved:	280	56%	384	61%
– roof catchment	2		3	
– protected spring	147		211	
– shallow well	40		48	
– borehole	71		104	
– piped water	20		18	
Unimproved:	222	44%	243	39%
– river, lake	55		46	
– pond, pool, dam	32		27	
– unprotected spring	135		170	

Analysing the total material, the children of households using an unimproved water source had a statistically non-significantly increased risk of diarrhoea relative to those from households using an improved water source (OR 1.25, CI 0.99–1.59, p 0.06).

The association of the use of an unimproved versus improved water source with diarrhoea was also analyzed in subpopulations defined by feeding and age of the child, hand-washing practices, distance from the water source and number of children aged < 15 years. The increase in the occurrence of diarrhoea associated with the use of an unimproved water source was not significant among the 124 exclusively breast-fed children (OR 1.20, CI 0.55–2.61, p 0.6), nor among the 700 children on weaning food (OR 1.20, CI 0.89–1.62, p 0.24) or the 304 children on solid food (OR 1.44, CI 0.90–2.31, p 0.13). Similarly, the modest increase in the risk of diarrhoea associated with the use of an unimproved water source was not significant in the age groups of infants (< one year of age) and children aged 12–23 months (OR 1.16, CI 0.84–1.60, p 0.4 and OR 1.15 CI 0.72–1.84, p 0.65), but it was among the children aged 24–59 months (OR 1.83, CI 1.02–3.28, p 0.04). The same risk was also significant when calculated for age group 12–59 months (n. 522), but the statistical significance was not seen after controlling for washing of the child's hands before meals (OR 1.37, CI 0.96–1.97, p 0.09). Considering only the 411 children aged 12–59 months whose hands were washed before meals, the use of an unimproved water source was associated with a statistically significantly increased occurrence of diarrhoea (OR 1.55, CI 1.03–2.33, p 0.04).

There was only a minor, non-significant increase in diarrhoea associated with the use of an unimproved water source among the 811 children of the households located less than 500m away from their water source (OR 1.12, CI 0.85–1.49, p 0.4). If the distance from water source was 500m or more (n. 318), the use of an unimproved water source increased the occurrence of diarrhoea by 70% (OR 1.70, CI 1.08–2.27, p 0.02).

If the mother had one or two children below 15 years of age no association between water source and diarrhoea was found, but in the families with 3 or more children the use of an unimproved water source was associated with a 53% increase in the occurrence of diarrhoea (OR 1.53, CI 1.09–2.14, p 0.01).

In summary, the use of an improved water source reduced the occurrence of diarrhoea significantly in the case of children aged 2–5 years, those whose water source was more than 500m away, those aged 1–5 years who washed their hands before meals and those whose mother had 3 or more children under 15 years of age.

The classification unimproved versus improved drinking water source was used in the logistic regression analysis and confounder score analysis.

Considering the total material, the use of untreated surface water (river, lake, pond or dam) as a source of drinking water was associated with an increased occurrence of diarrhoea in children under five years of age as compared with the use of other types of water source (OR 1.59, CI 1.14–2.23, p 0.006). Since the longest mean distance from the household was to a river, lake, pond, pool or dam, an analysis was also performed controlling for distance (≤ 500m/ > 500m), but this still showed a higher occurrence of diarrhoea in children when surface water was used (OR 1.54, CI 1.1–2.16, p 0.01).

When the children of the households using a borehole as their water source were compared with those from the households using other water sources, a tendency for a reduced diarrhoea morbidity was seen, but the confidence interval was broad (OR 0.83, CI 0.60–1.15, p 0.3). The finding was similar after controlling for distance from the borehole (≤ 500m/ > 500m) (OR 0.81, CI 0.59–1.12, p 0.2).

5.3. Quantity of water collected per person in the household

The mean quantity of water collected per person per day in the households of the diarrhoea children was 15.3 litres and that in the households of the control children 15.5 litres.

There were 110 households of diarrhoea children and 128 households of control children which collected 10 l or less water per person per day, while households which collected more than 20 l water per person numbered 114 in the diarrhoea group and 153 in the control group. No difference in the risk of diarrhoea morbidity could be found between the children of households collecting 10 l or less water per person and those collecting more than 10 l (OR 1.09), or between the children of households collecting 20 l or less water/person/day and more than 20 l/person/day (OR 1.06). Similarly no difference in the occurrence of diarrhoea in the children was found when comparing those using < 10 l/person/day with those using > 20 l/person/day (OR 1.15).

5.4. Distance from source of drinking water

The mean distance from the source of drinking water was 564 m in the diarrhoea group and 503 m in the control group. In both groups the mean distance from the water source was greatest if a river or lake was used. There were 17 villages in which 4 or more mothers reported a fetching water over distance longer than 500 m.

Distance of over 500 m from the drinking water source increased the occurrence of diarrhoea in children (OR 1.36, CI 1.04–1.75, p 0.02).

The distance to the water source of over 500m versus ≤ 500m was included as a variable in the logistic regression analysis and confounder score analysis.

5.5. Other variables and diarrhoea

5.5.1. Education and age of the mother

The children of the illiterate mothers (n. 160) had 33% less diarrhoea (OR 0.67, CI 0.48–0.95, p 0.02) than those of the literate mothers. This unexpected finding had a wide 95% confidence interval when illiteracy/literacy was controlled for age of the mother (< 30y/≥ 30y), (OR 0.73, CI 0.51–1.04, p 0.09). When controlling for the age of the child (< 12 months, 12–23 months, > 24 months) a reduced occurrence of diarrhoea was still associated with illiteracy on the part of the mother (OR 0.70, CI 0.50–0,99, p 0.04).

No differences in diarrhoea morbidity were found when the children of mothers who had completed at least primary school were compared with those of mothers who had not finished primary school.

The education of the mother was included in the logistic regression analysis and confounder score analysis in the form of a dichotomous variable: mothers who had not completed primary school vs. mothers who had completed at least primary school.

5.5.2. Feeding of the child

In the age group 1–6 months the exclusively breast-fed infants had a significantly lower occurrence of diarrhoea than the non-breast-fed ones OR 0.51 (CI 0.31–0.83, p 0.006), but the association was not statistically significant after weighting the calculation for age strata (< 4 months and 4–6 months) (OR 0.64, CI 0.34–1.23, p 0.14).

The children on weaning food had a highly significantly higher occurrence of diarrhoea than those on solid food of adult type (OR 1.70, CI 1.29–2.25, p < 0.001), and this effect persisted, although statistically less significant, after stratification for age (< 12 months, 12–24 months and ≥ 25 months) and weighting the occurrence figures according to the size of the age strata (OR 1.47, CI 1.01–2.17, p 0.05).

5.5.3. Existence and use of a latrine

No difference in the occurrence of diarrhoea could be found between the households with and without a latrine. Existence of a latrine in the household was not included in the logistic regression or confounder score analysis.

There was no difference in the diarrhoea morbidity of the child as to whether the mother used a latrine or not. Thus this factor was likewise not included in the logistic regression analysis or confounder score analysis.

The children defecating behind the house or in the garden (n. 307) had higher occurrence of diarrhoea than those defecating in a latrine (n. 70) (OR 1.84, CI 1.04–3.23, p 0.03). The children were grouped for the logistic regression analysis and confounder score analysis into those aged ≥ 1 year and defecating in a latrine and others.

5.5.4. Handwashing

Only 13% of the mothers of the diarrhoea infants (aged 0–11 months) washed their hands before feeding the infant, the corresponding percentage for the mothers of the control infants being 14%. Reported handwashing had a slight decrease of 10% in diarrhoea morbidity associated with it (OR 0.90). Although not statistically significant, this factor was included in the logistic regression and confounder score analyses in the form: mothers of infants (aged 1–11 months) washing their hands vs. other mothers.

The hands of children aged 1–5 years were washed before meals in 70% of the diarrhoea cases and 86% of the control cases. The excess diarrhoea morbidity among the children whose hands were not washed before meals was clear (OR 2.67, CI 1.73–4.13, $p < 0.001$). Thus, if the hands of a child aged 1–5 years were not washed before meals the danger of developing diarrhoea was significantly increased.

The occurrence of diarrhoea was also increased if the child's hands were not washed when considering only the subgroup of children on ordinary family food (OR 3.02, CI 1.48–6.19, p 0.002), and the effect remained similar (OR 3.06, CI 1.49–6.38, p 0.001) when handwashing was controlled for the mother's education (completed primary school or less).

Children aged ≥ 12 months washing their hands before meals vs. all other children was included as a variable in the logistic regression and confounder score analyses.

5.5.5. Cultivation of Enterobacteriaceae from the hands of the mothers of infants and children aged 1–5 years

The hands of the mothers of the infants with diarrhoea were found to be contaminated in 34% of cases at the health centres (in 19% at home), the corresponding percentage for the mothers of the control infants being 39% (38% at home). A positive cultivation for Enterobacteriaceae from the right hand of the mother of an infant (0–11 months) at the health centre was not significantly associated with the infant's diarrhoea (OR 0.82, CI 0.58–1.17, p 0.3). Contamination of the mother's hands with Enterobacteriaceae was not included in the logistic regression or confounder score analysis.

30% of the cultivations from the hands of children with diarrhoea were positive at the health centres (23% at home), the corresponding percentage for the control children being 28% (28% at home). No association was found between a positive growth of Enterobacteriaceae from the right hand of the child and the occurrence of diarrhoea

(OR 1.05, CI 0.7–1.6,p 0.8). Contamination of the child's hand with Enterobacteriaceae was not included in the logistic regression or confounder score analysis.

5.5. Logistic regression analysis

On the basis of the evaluation of the significance of the individual variables regarded as confounding factors and the type of water source (improved/unimproved), a total of 13 variables were included in the logistic regression model (Table 8). The increase in the occurrence of diarrhoea associated with the use of an unimproved water source was similar to that in the univariate analysis. A distance of over 500m from the water source was associated with a 31% increase in the occurrence of diarrhoea, also a similar result to that obtained in the univariate analysis. The factors associated with a decreased occurrence of diarrhoea were age over 2 years, age under one year, breastfeeding and a child over 1 year of age whose hands were washed before meals.

Mother's schooling, number of children under 15 years of age, mother's age, mother's handwashing before feeding the infant, and use of a latrine by a child aged 1 year or more were not significant for diarrhoea morbidity among children under 5 years of age in this analysis.

Table 8. Comparison of univariate (OR) and adjusted odds ratio (aOR) values (with CI and p) for the variables included in the logistic regression analysis (n. 1123).

Variable	Univariate OR	Logistic regression aOR	Logistic regression 95% CI	p
Age (vs.12–23 months)				
– ≤ 2 years	0.50	0.44	0.30–0.67	<0.001
– < 1 year	0.92	0.49	0.31–0.75	0.001
Child exclusively breast-fed/others	0.49	0.49	0.32–0.75	0.001
Child ≥ 1 y using a latrine/other children	0.96	0.77	0.40–1.48	0.44
Child 1–5 y washing hands/other children	0.37	0.58	0.37–0.90	0.017
Mother of infant washing hands/others	0.90	0.85	0.52–1.38	0.5
Mother's age (vs.20–29 y)				
≤ 19 y	0.95	0.79	0.52–1.18	0.3
≤ 30 y	0.74	0.79	0.40–1.48	0.2
Education of mother < primary	1.06	1.11	0.87–1.43	0.4
Number of children (vs. 2–3)				
– 1 child	1.15	1.07	0.76–1.50	0.7
≥ 4children	0.86	0.93	0.67–1.28	0.7
Distance > 500m from water source/less	1.36	1.31	1.00–1.71	0.05
Unimproved water source	1.25	1.26	0.98–1.61	0.08

5.7. Analysis by confounder score

The greatest protective influence against diarrhoea in the confounder score analysis when fitting a logistic model containing the same variables as in the logistic regression analysis to the subcohort of users of an improved water source was attributed to age over 2 years, age under 1 year, washing of hands before meals in children aged 1–5 years and breastfeeding.

Table 9 shows the diarrhoea cases by the use of unimproved/improved water source in quintile strata. The children in each quintile are comparable with respect to the baseline risk, those in the first quintile having the lowest risk. The occurrence of diarrhoea with reference to the use of an unimproved versus improved water source was used for calculating the odds ratio and its confidence interval in each quintile stratum. The stratum-specific odds ratio for diarrhoea contingent on an unimproved water source increased from 0.9 in the fourth quintile to 1.7 in the first quintile. The odds ratio pooled over the strata was 1.2 (Table 9).

Table 9. Numbers of children, numbers of children with diarrhoea, and odds ratio for diarrhoea by use of an unimproved/improved water source, in quintile strata.

	Improved water source		Unimproved water source		Unimproved/improved water source	
Stratum	n. of children	with diarrhoea n.	n. of children	with diarrhoea n.	OR	CI
1	202	51	134	49	1.7	1.1–2.7
2	126	53	98	47	1.3	0.7–2.2
3	132	62	84	42	1.1	0.7–2.0
4	107	55	84	41	0.9	0.5–1.6
5	93	57	63	41	1.2	0.6–2.3
all	664	280	465	222		

pooled OR over strata 1.2, CI 1.0–1.6
* Stratification by quintiles according to the distribution of the confounder scores among the children of the households using an improved water source.

The impact of the type of water source on diarrhoea in the children is seen in the first quintile, which has the lowest confounding risk factors. This group contained only 1 child aged 12 to 23 months in the diarrhoea group and one in the control group. 39% of the diarrhoea group were infants and 40% of the control group, and 95% of the infants in the diarrhoea group and 91% in the control group were being breast-fed. All the children aged 12 months or more in this quintile washed their hands before meals. 22% of those aged ≥ 1 year in the diarrhoea group and 29% of the same age group among the controls used a latrine. The distance from the water source was ≤ 500m in 77% of cases in the diarrhoea group and 78% in the control group.

When the score for other risk factors was high, the type of water source had little additional impact on the risk of diarrhoea. Thus there were no children aged two years or more in the fifth quintile, which conversely contained 23% infants in the diarrhoea group and 28% in the control group, none of whom was being breast-fed. Among the children aged 12 to 23 months, 15% in the diarrhoea group had their hands washed before meals and 19% in the control group. 1% and 2% of these children respectively used a latrine. The distance from the water source was over 500m in 57% of cases in both groups.

5.8. Bacteriological quality of water from different sources

The best bacteriological quality, measured in terms of faecal coliform growth, was found in the boreholes. This was true during both the dry season and the rainy season. The shallow wells with hand pumps and the protected springs were markedly more contaminated than the boreholes, but cleaner than the unprotected springs during the dry season. The contamination of the shallow wells with hand pumps increased more than that of the protected springs during the rainy season. The number of samples from unprotected springs in the rainy season was too low for any reliable comparison to be made, Tables 10 and 11.

Table 10. Bacteriological quality of water from different sources, dry season.

Type of water source	n.	Quality		
		*Clean %	**Moder. contaminated %	***Heavily contaminated %
Unprotected springs	85	46	13	41
Protected springs	59	78	12	10
Shallow well	61	75	18	7
Boreholes	50	96	2	2

* faecal coliforms 0–5 c.f.u./100ml
** faecal coliforms 6–49 c.f.u./100ml
*** faecal coliforms over 50 c.f.u./100ml

Table 11. Bacteriological quality of water from different sources, rainy season.

Type of water source	n.	Quality		
		*Clean %	**Moder. contaminated %	***Heavily contaminated %
Unprotected springs	6	66	0	34
Protected springs	64	50	39	11
Shallow well	62	45	32	23
Boreholes	55	96	4	0

contained
* faecal coliforms 0–5 c.f.u./100 ml
** faecal coliforms 6–49 c.f.u./100 ml
*** faecal coliforms over 50 c.f.u./100 ml

5.8.1. Unprotected springs

46 % of the unprotected springs (n. 85) were clean (faecal coliforms 0–5 c.f.u./100ml) during the dry season, 13 % moderately contaminated (faecal coliforms 6–49 c.f.u./100ml) and 41 % heavily contaminated (faecal coliforms over 50 c.f.u./100ml), while 4 out of the 6 unprotected springs examined during the rainy season were clean and 2 heavily contaminated. Although the number of samples taken during the rainy season was small, the result suggests that contamination could be less frequent at that time.

5.8.2. Protected springs

78% of the protected springs (n. 59) had clean water during the dry season, 12% were moderately contaminated and 10% were heavily contaminated. During the rainy season, 50% of the samples from protected springs (n. 64) were clean, 39% moderately contaminated and 11% heavily contaminated. Thus the protected springs were less contaminated with faecal coliforms during the dry season than during the rainy season, but the proportion of heavy contamination remained constant throughout.

5.8.3. Shallow wells with hand pumps

Clean water was found in 75% of the shallow wells with a hand pump (n. 61) during the dry season, moderately contaminated water in 18% and heavily contaminated water in 7%. During the rainy season, only 45 % of these wells (n. 62) proved to be clean, 32 % were moderately contaminated and 23 % were heavily contaminated. Like the protected springs, the shallow wells with hand pumps were more contaminated with faecal coliforms during the rainy season, the percentage with moderate contamination being almost doubled and the percentage with heavy contamination more than tripled.

5.8.4. Boreholes

96% of the boreholes (n. 50) contained clean water during the dry season, only one being moderately contaminated and one heavily contaminated. A mistake in sampling procedure was suspected in the one case of heavy contamination, but it was not possible to obtain a new sample during the dry season. The sample taken from this same borehole in the rainy season was clean. The sample was clean in 96 % of the boreholes examined during the rainy season (n. 55) and moderately contaminated in 4%. The results show that the borehole water was bacteriologically almost always clean in both the dry season and the rainy season.

5.9. Water in the household

5.9.1. Contamination with Enterobacteriaceae

Water storage samples for the cultivation of Enterobacteriaceae were taken in 210 homes, and 76% of them were found to be contaminated (over 1 colonies/sq.cm., corresponding to more than 10 000 Enterobacteriaceae/ml).

Table 12. Growth of Enterobacteriaceae in the water stored in the households (n. 210).

Enterobacteriaceae	diarrhoea group (n. 93) %	control group (n. 117) %
> 1 c.f.u./sq.cm.	72	80
total	100	100

5.9.2. Source of drinking water and contamination of household water with Enterobacteriaceae

The source of the water used by a household had little influence on its contamination during storage in the house, 68% of the 34 samples of stored borehole water being contaminated with Enterobacteriaceae even though this water was free of faecal coliforms at source in 96% of cases. The samples taken from the household water fetched from other sources showed in a slightly higher proportion of contamination with Enterobacteriaceae, notably in the case of surface water, Table 13.

Table 13. Growth of Enterobacteriaceae in water stored in the household, by type of water source.

Water source	Enterobacteriaceae growth		
	No growth %	≤ 1 c.f.u. /sq.cm. %	> 1 c.f.u /sq.cm. %
River, pond, lake, unprotected spring (n. 36)	–	17	83
Protected spring (n. 97)	3	19	78
Shallow well with hand pump (n. 39)	8	20	72
Borehole (n. 34)	9	23	68
Piped water, roof catchment (n. 4)	25	0	75
Total (n. 210)	5	19	76

– = less than 1

5.9.3. Storage vessel for water and it's cleaning

The most common storage vessel for household water was a locally manufactured large clay pot (approximately 40 l), which was used in 93% of the households of both the diarrhoea and control patients. A plastic jerrycan was used for a storage in 6% of the households of diarrhoea patients and 5% of those of control patients.

The water storage vessel was cleaned daily in 24% of the households with a diarrhoea child and 20% of those with a control child, and weekly cleaning in 74% and 79% respectively. No difference in the risk of diarrhoea was detected in relation to the frequency of cleaning the water storage vessel.

Table 14. Growth of Enterobacteriaceae by frequency of cleaning the water storage vessel.

Enterobacteriaceae/ml	Cleaning of water storage vessel		
	Daily n. 47	Less frequently n. 161	No data on cleaning n. 2
≤ 1 c.f.u./sq.cm.	15	35	0
> 1 c.f.u./sq.cm.	32	12	62

The water storage vessel was cleaned daily in 30 % of the households where it had an enterobacterial growth rate of ≤ 1 c.f.u./sq.cm. and in 20 % of those where it was more contaminated.

6. DISCUSSION

6.1. Methodology

Bacterial diarrhoea has been shown to be more susceptible to improvements in water supplies than viral diarrhoea (Baltazar 1991, Zoysa & Feachem 1985). Since the aim of this research was to show the influence of the use of improved water sources on the occurrence of diarrhoea, it was timed to take place in the warm rainy season, when the peak in bacterial diarrhoea occurs (Black *et al.* 1982a, Broek *et al.* 1993, Guerrant *et al.* 1983, Guerrant *et al.* 1986, Mertens *et al.* 1990a, Pinfold 1990b, Pinfold *et al.* 1991). No bacteriological or virological tests to determine the origin of diarrhoea were feasible. The assumption of a predominantly bacterial aetiology for the diarrhoea was thus based on experiences reported elsewhere.

The lively discussion on methodological issues relevant to the assessment of the impact of the improved water supplies on health shows how difficult it is to measure the influence of one, albeit important factor on the occurrence of a disease when several factors, either interrelated or partially superimposed, are involved in the spread of the disease.

In quasi-experimental, cohort and cross-sectional studies comparability can seldom be achieved between the group with improved water supplies and the control group, and it is difficult to adjust for this non-comparability during analysis of the data (Cook & McAnany 1979). The collection of a sample of the required size is expensive and takes a long time, and it is difficult to maintain the field worker's efficiency at its initial level. Misclassification of the disease is more common if the recall period is long.

The case-control method was selected for several reasons. The sample size required was manageable with the resources available during the field period, and collection of the sample could be adjusted to occur in the warm rainy season by using several health facilities at the same time. This arrangement also reduced the possibility of clustering in confounding variables and follows the recommendations of earlier reviews (Briscoe and al. 1985, 1986).

In order to control for possible bias caused by the limited use of certain types of water sources or by the distance from the water source together with socio-economic status among the users of unimproved and improved water sources, two of the health centres selected for the survey were outside the area of the bilateral water programme. No statistical difference in the use of an unimproved/improved water source or in any of the confounding variables was observed between the area belonging to the water project and that outside it. The improved water sources in Western Province are not limited to the immediate vicinity of health facilities, and there are protected springs, shallow wells with hand pumps and boreholes with hand pumps distributed in the terrain irrespective of the location of the health centres (Maps 2, 3, 4 and 5).

The inclusion of areas served by six health centres was intended to ensure a sufficient number of cases and controls and a mix of socioeconomic status.

Enrolment in the series was restricted to children whose homes were within a radius of 5 km of the health centre. The health centres concerned here are the only providers of modern health care in their areas. They were free of charge for children as out-patients, so that the probability of socio-economic status affecting attendance would be small, and where any existed its effect would be similar for the children with diarrhoea and with ARI.

No stool samples were taken in the present cases, and the diagnosis of acute diarrhoea was based on a report by the mother and backed up with clinical findings by the community nurse. Diagnoses based on mothers' reports of frequent loose stools have been found elsewhere to be sensitive and specific (Kalter *et al.* 1991). It was also assumed that milder or non-infectious bouts of diarrhoea probably very seldom cause a mother to bring her child to the clinic, which she does only when the disease is serious. The children enrolled in this series received routine treatment and advice, and the mothers could not expect any additional benefits from the research situation. Since the recruitment period was short, only 4 weeks, the interest of the health centre staff was maintained despite the additional workload. Thus it is reasonable to conclude that misclassification of cases as diarrhoea is rather low, and since any misclassification that did exist would probably affect those belonging to various exposure groups in a similar manner, the result would tend to reduce the difference in the risk of acute diarrhoea between the exposed and non-exposed cases, e.g. those using an unimproved/improved water source.

The controls selected were children with ARI, which was defined clinically without laboratory tests. These diseases are often very severe in children in rural Western Kenya and are even more common than acute diarrhoea (National Council for Population and Development, 1989), but are not related to water supplies. On the other hand, more severe cases of ARI may be similar in severity to acute diarrhoea, so the tendency to seek treatment at a health centre would be similar. It thus seems realistic to assume that misclassification of the controls in the present series was also fairly low, and again any remaining misclassification, being non-differential with respect to the exposure classes, would tend to decrease the estimated risk difference between the exposure groups.

In similar case control studies elsewhere (Baltazar *et al.* 1988, Briscoe *et al.* 1988, Young & Briscoe 1987) the selection of acute diarrhoea cases and control disease cases did not introduce serious misclassification errors. The level of training of the clinical personnel needs to be relatively high and supervision of the selection process is required with less well trained personnel (Briscoe *et al.* 1988). In this series the nurses at the health centres were those routinely working in clinics for sick children, but they received additional training in the sampling and collection of patient histories and were supervised. However, as stated earlier, any misclassification would again affect different exposure classes equally.

Information on the type of water source used is not usually regarded as a sensitive issue. The true usage of given types of water source can therefore be regarded largely as a problem of reliability of the information provided by the mother. A recent report from Nicaragua claims excellent repeatability of anamnestic data regarding water sources (Sandiford *et al.* 1990). In Sri Lanka, however, where some of the users of unimproved water sources as reported at health centre were found at home to use an improved water source and vice versa, the authors presumed that the difference reflected real changes in habits due to temporary fluctuations in the availability of water (Mertens *et al.* 1990a).

In the present series the home visit information intended for validating the anamnestic data was biased towards users of improved water sources and could therefore not be used for validation purposes. Regarding the external similarity of shallow wells and boreholes, both of which have hand pumps, it is possible, that differentiation between these types may have been difficult for the mothers. This would not have affected the comparison between the use of improved and unimproved water sources, however, since both shallow wells and boreholes are regarded improved.

It proved possible to employ the case-control method in this field setting, and a special effort was made during the field period and analysis to avoid biases that could distort the results. It is thus reasonable to assume that the methodology used did produce sound results.

6.2. Type of water source used and diarrhoea

The increased risk of acute diarrhoea in small children associated with the use of untreated surface water as compared with other sources supports the view that the use of a river, pool, dam or lake as a water source forms a significant health hazard in this densely populated area with a tropical climate, where considerable contamination of surface water may occur. The result is also in line with the finding that grossly contaminated water increases the rate of diarrhoea (Moe *et al.* 1991). The increased contamination of rivers and streams in areas with a higher population density reported elsewhere (Sandiford *et al.* 1989) may be possible in this geographical area too, although no bacteriological verification of the quality of the surface water was attempted here.

On the other hand, comparison of the use of unimproved water sources (surface water and unprotected springs) and improved water sources failed to yield any significant difference in the occurrence of diarrhoea. The result suggests that the use of unprotected springs was associated with a lesser risk of diarrhoea than the use of the surface water at this period. It can also mean, that the risks of acute diarrhoea in small children associated with the use of unprotected springs and improved water sources may be very close to each other.

Our findings nevertheless support the notion of a threshold effect of water quality on the occurrence of diarrhoea (Briscoe 1984, Shuval *et al.* 1981). The use of an improved water source alone does not have a visible effect on diarrhoea morbidity when the risk factors are very high or very low. In our setting the risks of small children contracting diarrhoea were high, and it is thus reasonable assume, that very low levels of risk did not occur in this rural setting. When risks other than the type of water source used are more important for the onset of diarrhoea, or when several risks accumulate, improvement of the water source is not reflected in a change in the occurrence of diarrhoea. Thus the use of an unimproved water source did not carry with it any increase in the occurrence of diarrhoea among weanlings, repeatedly reported to have the highest incidence of diarrhoea (Agarwal *et al.* 1986, Aziz *et al.* 1990, Bern *et al.* 1992, Broek *et al.* 1993, Clemens & Stanton 1987, Daniels *et al.* 1990, Huilan *et al.* 1990, Huttly *et al.* 1987, Snyder and Merson 1982, Tonglet *et al.* 1992, Yeager *et al.* 1991). The finding was similar among exclusively breast-fed infants, nor was any difference seen in children aged ≥ 1 year who did not wash their hands before meals.

On the other hand, children who had low risk scores benefited from the use of an improved water source. Those aged 1 year or over whose hands were washed before meals had less diarrhoea if the household used an improved water source, and even those aged 2 years or over, who have been reported elsewhere to have a relatively low incidence of diarrhoea, had a reduction in diarrhoea associated with an improved water source.

Our finding is consistent with other surveys which report only limited benefit from an improved water supply in certain age groups (Gorter *et al.* 1991, Henry *et al.* 1990a, Huttly *et al.* 1990, Ryder *et al.* 1985). When modifications in environmental and behavioural hygiene are added to the improvement of the water supply, the effect of the latter per se becomes visible, as shown by the results obtained in Bangladesh (Aziz *et al.* 1990, Black *et al.* 1982b, Clemens & Stanton 1987), Malawi (Young & Briscoe 1987), the Philippines (Baltazar *et al.* 1988), Sri Lanka (Mertens et al. 1990a,b,c), Lesotho (Daniels 1990), Nicaragua (Gorter *et al.* 1991) and Zaire (Tonglet *et al.* 1992). Besides water supplies, it is of paramount importance to improve hygienic practices and environmental hygiene if substantial health benefits to the community are to be achieved. In the light of the evidence that has been accumulated until now, one could ask if any water project which does not include and implement a major hygienic component can improve the health of those most at risk.

Other researchers have concluded that it may not be beneficial to health or cost-effective to use the limited financial resources available in developing countries to provide high quality water supplies in the absence of other improvements in hygiene and sanitation (Moe *et al.* 1991). Although improvement of hygiene is usually among the targets of water projects, it is in practice the production and maintenance of water sources that consumes the bulk of the human and material resources. The modest position of hygienic issues in water projects may be partly influenced by the division of labour between the ministries handling issues of health and water resources. Since progress in hygiene can also enable the effect of an improved water supply to become visible, it is in everybody's interest to find some functional solution to the connection between hygienic issues and the improvement of water supplies.

If attention is not paid to hygienic practices, water storage and handling and environmental conditions, the impact of improved water supply on the occurrence of diarrhoea may be limited to those subjects having the smallest risk factors for diarrhoea.

At the same time, of course, one has to remember when assessing the value of improved water supplies that the health effect measured in terms of diarrhoea morbidity in children is only one aspect. Improved water supplies can control cholera, typhoid, amoebiasis, giardiasis and a variety of helminthic diseases, and the spread and severity of many diseases (e.g. trachoma, scabies) may be partially related to a lack of water and to poor hygiene.

The preparation of safe food can be enhanced by an adequate water supply, and the availability of water near the home, or at least at a reasonable distance, can release the women to spend more time on other activities such as child care, tending the garden and animals or other small-scale economic activities. The benefits to private industry, commerce, schools and housing achieved through improved water supplies cannot be measured in terms of reduced childhood disease alone. However, as other authors have concluded, in all of these cases much more is required than the installation of water facilities in order to reap the full benefits from the investments in water supplies (Okun 1988).

6.3. Quality of water at the source and at home

The quality of water at source, measured in terms of faecal contamination, shows seasonal variations in climates where rainy and dry seasons occur, and these variations differ according to the type of water source (Barrel and Rowland 1979b, Blum *et al.* 1987, Laike 1992, Lehmusluoto 1987, Mertens *et al.* 1990a, Moe *et al.* 1991, Sandiford *et al.* 1989, Tomkins *et al.* 1978, Wright 1982). Seasonal variation was found in all the types of water source examined here except the boreholes, which were similarly clean on both seasons. Surface runoff is abundant during the rainy season, and this carries contaminated material into the springs and wells despite the protective structures. This is particularly likely to happen in a densely populated hilly area like the Western Province of Kenya.

Heavy contamination occurred in two fifths of the unprotected springs during the dry season. The samples obtained from the unprotected springs during the rainy season were few in number and the lesser degree of contamination may have occurred by chance. In the protected springs only the moderate level of contamination increased during the rainy season, and the same occurred to a greater extent in the case of the shallow wells, in which heavy contamination also increased during the rainy season. Comparing these two water sources, the structure of a protected spring allows a continuous overflow of water, which may result in relatively lesser contamination than in a shallow well, where the water stays until pumped out. In practice, if only grossly contaminated water forms a significant health hazard, protected springs are less hazardous during the rainy season than shallow wells with hand pumps, while there is no difference in the health hazard between the two during the dry season.

On the other hand, the provision of drinking water to a community does not necessarily mean that the water consumed is drinkable. Water stored at home has repeatedly proved to be more contaminated than at the source (Black *et al.* 1982b, Blum *et al.* 1990, Laike 1992, Lehmusluoto 1987, Molbak *et al.* 1989, Sandiford *et al.* 1989), and in some studies contamination was more prominent during the rainy season (Henry *et al.* 1990b, Huttly *et al.* 1990). In this survey cultivations were performed from the water stored at home only during the rainy season, and the results are consistent with those mentioned above, i.e. the water was contaminated with enteric bacteria at home even if drawn from a borehole. Transportation, storage and handling of water are all potentially detrimental to its quality and special attention should be paid to these aspects in order to maintain the quality of water when stored in the household. A general knowledge of hygienic practices for the handling of water may support other health education efforts aimed at reducing the danger of the spread of diseases.

Contaminated water, as assessed from samples taken during the home visits, was found to be just as common in the households of the control patients as in those of the diarrhoea patients, which raises the question of the significance of contaminated household water for diarrhoea in children. The number of households examined was limited, however, and most of the children in these households were at the age of high diarrhoea incidence, so that the effect of water quality was not likely to be seen unless connected with reduction in other risk factors, including unsatisfactory hygiene. It is also possible that the contamination of water with enterobacteriaceae confirmed here involved types of bacteria of relatively low pathogenicity, so that no significant association of household water contamination with diarrhoea could be demonstrated.

Although water may be the major vehicle of infection only in limited cases, it can, if adequately used, even when slightly polluted, substantially reduce the risk of infection from dirty hands and dirty kitchen utensils.

6.4. Distance from water source and quantity of water used

A distance of over 500m from the water source increased the risk of contracting diarrhoea in this setting. Our result is consistent with observations made in Nicaragua and Nigeria, where a long distance from the home to the water source or a long water collection time increased the risk of diarrhoea compared with the children of households with a water source nearby (Gorter *et al.* 1991, Huttly *et al.* 1990). Similar findings were also reported from Zaire, where children of households located less than five minutes' walk from the public standpipe had a markedly lower incidence of diarrhoea (Tonglet *et al.* 1992). Elsewhere shorter water collection journeys have been found to be related to an increased per capita water consumption (Cairncross & Cliff 1987, Sandiford *et al.* 1990), which in turn is linked with a reduction in diarrhoea morbidity (Freij & Wall 1977, Ryder *et al.* 1985). The quantity of water used has not been shown to be dependent on the type of water source, except for in-house or yard sources, and thus the distance from the water source appeared to be the most important determinant of the quantity of water used (Mertens *et al.* 1990b, Sandiford *et al.* 1990).

Of the 176 villages where a water fetching distance longer than 500 m was reported by mothers, 17 were ones in which more than 3 mothers reported such a distance. All 17 villages lie inside the area covered by the Kenya-Finland Western Province Water Supply Project, which indicates, that the project is concentrated in an area which is in need of greater access to water but that there still are villages in which several households are far from the water source.

The fetching of water from a long distance increases the time required for this and leaves mothers less time for other household tasks. The time factor is an important one, especially when all the children are small and require care and attention from the mother without being able to help with the domestic tasks. In such cases the mother is usually young and her social position in the extended family poor. The long journey to fetch water may also lead to the use of a smaller quantity of water per person per day. Although the mean amount of water collected was slightly lower in this study in the households whose water source was over 500 m away, the difference was not significant. It was found, however, that washing of the child's hand before meals was less frequent if the distance from the water source was more than 500m. This could be a result of the more limited time available for child care, less knowledge about hygiene or a greater need of water for other purposes, or very probably a combination of all these factors.

The quantity of water collected may vary from day to day depending on family size, size of the water vessel and daily fluctuations in use. This may be one of the causes of the lack of any association between the quantity of water used per person and diarrhoea in a child in the present series. The inconsistency in the number of household members (visiting members of the extended family, absence of family members due to schooling or working in other areas) has also been recorded in a previous survey carried out in the area (Water, Sanitation and Health Care Survey, 1986).

When the water source is located so far away that the time needed for fetching the water jeopardizes the carrying out of other necessary tasks in the household, economics may be made in the water consumption to a degree which adversely affects hygienic habits and increases the occurrence of acute diarrhoea in small children.

6.5. Age and feeding of the child

The results of a recent study of the relationship between water quality and human health in Malaysia illustrate the well known dependence of the incidence of diarrhoea on age, one third of all diarrhoea cases occurring in children aged $\leq$ 4 years even though they represented only 13% of the population (Lonergan & Vansickle 1991). The peak incidence of diarrhoea in children under five years of age is mostly reported to occur at 6 to 11 months (Aziz *et al.* 1990, Bern *et al.* 1992, Clemens & Stanton 1987, Daniels *et al.* 1990, Huilan *et al.* 1990, Huttly *et al.* 1987, Snyder and Merson 1982, Tonglet *et al.* 1992, Yeager *et al.* 1991), or occasionally at 6 to 18 months (Agarwal *et al.* 1986) or between 18 and 24 months (Broek *et al.* 1993).

Many physiological and social changes occur during the first two years of life, and most of them can play a role in morbidity with respect to diarrhoea (e.g. immunity, feeding patterns, development of motor ability, and changes in the social situation of the mother and child). The occurrence of diarrhoea was seen in this material to be greater in children under two years than in older children, as reported elsewhere. Diarrhoea in children is closely correlated with age and feeding, and any analysis of the impact of the type of water source on this disease in children under five should take account of these two factors.

Exclusive breastfeeding has repeatedly been shown to be associated with a lower incidence of diarrhoea than feeding with weaning food (Aziz *et al.* 1990, Badruddin *et al.* 1991, Brown *et al.* 1989, Gross *et al.* 1989, Huttly *et al.* 1987), although there are reports in which no significant association could be demonstrated between breastfeeding and low diarrhoea morbidity (Lonergan & Vansickle 1991). The exclusively breast-fed infants in the age group 1 to 6 months in the present series had a lower diarrhoea morbidity than the others of the same age, but there was a proportionally larger number of children aged three months or less among the control children, possibly due to earlier onset of the control disease. When the age structure was allowed for, a slightly lower rate of diarrhoea was still found among the exclusively breast-fed infants aged one to six months than among those on breast milk and weaning food.

The duration of breastfeeding varies from one country and area to another, and this is probably reflected in the age-related incidence of diarrhoea. In this series exclusive breastfeeding was a routine during the first three months but a rare exception after six months. On the other hand, weaning had seldom started before the age of 4 months, and only in a few cases did it continue beyond 2 years, when the children received the same food as eaten by the adult members of the family. Weaning foods are known to be more contaminated with pathogenic bacteria than water (Agarwal *et al.* 1986, Barrel and Rowland 1979a, Black *et al.* 1982a, Black *et al.* 1989, Guerrant *et al.* 1983, Henry *et al.* 1990b, Lloyd-Evans *et al.* 1984, Motarjemi *et al.* 1993, Rowland *et al.* 1978) and are likely to be an important source of infection. Under rural conditions and without modern facilities, weaning porridge is prepared in the morning and served several times, either heated a little or at the ambient temperature. Hygienic storage of food between meals is not easy, and it may not be assigned the importance it deserves. Restrictions on either time or fuel may easily prevent the preparation of fresh weaning food several times a day, and thus a child can be exposed to a considerable number of enteropathogens in the course of the day. Low immunity will increase the child's susceptibility to infections the more the younger the child is, while older weanlings have greater access to faecal contamination in their immediate surroundings due to their greater mobility. If a decrease in infant and weanling diarrhoea is to be achieved, prolongation of breastfeeding and better hygiene in the preparation and storage of weaning food may have first priority. On the other hand if water source were nearer, the time saved would give to the mother a better change of paying attention to hygiene also when preparing the food.

6.6. Education of the mother

The adult literacy rate is often interpreted as the strongest indicator of socioeconomic status (Shuval *et al.* 1981), and it was likewise assumed here that the education of the mother would be reflected in her socioeconomic status. Many reports confirm that maternal education is inversely associated with diarrhoea morbidity (Badruddin *et al.* 1991, Betrand & Walmus 1983, Daniels *et al.* 1990, Gorter *et al.* 1991, Gross *et al.* 1989, Tonglet *et al.* 1992, Schirnding *et al.* 1991), although there are also instances where no association was found (Stanton & Clemens 1987, Vathanophas *et al.* 1986). Several reports suggest that the education of the father is not reflected at all in the incidence of diarrhoea in children under five years of age (Alam *et al.* 1989b, Huttly *et al.* 1987, Tonglet *et al.* 1992, Vathanophas *et al.* 1986).

Our data revealed a reduced occurrence of diarrhoea among the children of illiterate mothers. The proportion of older, illiterate mothers was higher in the control group than in the diarrhoea group, however, and when the age of the mother was taken into account, the association of illiteracy with a lower occurrence of diarrhoea in the child was weak. It is possible either that the presumably negative effect of illiteracy per se may be compensated for by experience of life and child-rearing, or that the better social position of the older mothers of large families acts in the same direction as experience of life and child-rearing.

There was no difference in the occurrence of diarrhoea in children depending on whether the mother had a primary school education or less. It is possible that the formal school education gives knowledge whis is not easy to adapt to the prevailing conditions in rural areas, particularly to child rearing.

6.7. Latrine ownership and use

In an area of high population density the need for a latrine becomes evident, and a pit latrine was common as also reported earlier in Western Province (National Council for Population and Development, 1989). Although the ownership of a flush toilet was shown to be associated with a significant reduction in diarrhoea in children (Schirnding *et al.* 1991) and in the whole population (Lonergan & Vansickle 1991), research in rural areas has not demonstrated that the existence of a latrine is significantly related to diarrhoea in infants or children (Gorter *et al.* 1991, Huttly *et al.* 1990, Mertens *et al.* 1990b, Wright *et al.* 1991). Latrine ownership was associated with fewer episodes of diarrhoea among children in rural Lesotho, however, and more significantly so if family used more water and practised better personal hygiene (Daniels *et al.* 1990).

Since traditional pit latrines were almost universal in the present area, information on their use was of special interest, since a higher attack rates of diarrhoea have been found to be associated with defecation somewhere other than in a latrine (Yager *et al.* 1991). Since the mothers of the present diarrhoea and control children used the latrine to the same extent, attention was focused on the use of the latrine by the child.

Sanitary practices are an area of life where the likelihood of a correct answer in an inquiry is always open to question (Baltazar 1991, Briscoe *et al.* 1988, Curtis *et al.* 1993). Although some investigators have used direct observations together with home interviews when assessing latrine use (Baltazar *et al.* 1988, Curtis *et al.* 1993, Daniels *et al.* 1990, Stanton *et al.* 1987), the present results are based only on the interview with the mother. Defecation by the child in the compound compared with defecation in a latrine increased the risk of diarrhoea, but there was only a slight association between a reduced risk of diarrhoea in children aged one year or more and defecating in a latrine rather than anywhere else (diaper, compound, not known). Our finding nevertheless encourages the use of a latrine and the disposal of faeces in a latrine as measures for reducing the risk of environmental contamination and the occurrence of diarrhoea.

6.8. Hygienic practices

No direct observations of handwashing practices were made here and the data on handwashing are based on interview results. The results revealed a markedly increased occurrence of diarrhoea among the children aged one year or more who were reported not to have their hands washed before meals. The hands of a child who is moving about and playing in a compound to which domestic animals have access and where the children themselves may defecate are probably strongly contaminated. If the hands are washed before meals, the danger of spreading the contaminated material to the gastrointestinal system is decreased. Since meals are usually eaten together from a common pot, the danger of contaminating the whole family's food is also reduced if the child's hands are washed before meals, whereupon the adult members of the family will most probably also have the same habit. Handwashing had the strongest protective effect against the occurrence of diarrhoea in children in this setting. Thus diarrhoea in children after the first year of life seems essentially curtailable by means of enhanced washing of the hands. Since no large material investments are required, our finding supports prompt action to increasingly promote knowledge of this fact and the practice of regular handwashing. This is supported by findings from elsewhere, since washing the hands before meals or before preparing food has repeatedly been shown to result in reductions in diarrhoea (Aung and Hlaing 1989, Clemens & Stanton 1987b, Khan 1982, Thongkrajai *et al.* 1990, Vathanophas *et al.* 1986).

It is possible, of course, that the information given here by the mother did not reflect a regular habit as much as the mothers' general knowledge of desirable hygienic practices, but even knowledge of the significance of hygiene on the part of the person taking care of the child may be associated with a lesser occurrence of diarrhoea (Kalter *et al.* 1991). Besides hygiene with regard to the hands, other basic hygienic issues can be tackled when disseminating information on this topic, and positive traditions enhancing hygiene can be sought.

6.9. Contamination of the hands with enterobacteriaceae

The bacterial cultivations produced from the hands of the mothers of infants and the hands of older children reflect only a momentary situation which was not directly related to meals or defecation. It is therefore easy to accept the finding that there was no association between these results and the occurrence of diarrhoea. The contamination of the hands observed at the health centre may be partly attributable to the habit of shaking hands with friends there. Cultivations from samples taken before meals or after defecation would be more relevant for studying the impact of contamination of the hands on diarrhoea morbidity.

7. CONCLUSIONS AND RECOMMENDATIONS

The use of water from improved sources (protected springs, shallow wells, boreholes, roof catchment, piped supplies) brought with it a decline in the occurrence of diarrhoea in children under five years of age only among those children who ran a low risk of contracting diarrhoea as far as age, feeding habits and personal hygiene were concerned. This supports the threshold theory, in that the benefit of an improved water source for health can be seen only in the presence of other improvements, notably in hygiene, which reduce the child's risk of contracting diarrhoea. If the improvement of hygiene is not tackled together with the improvement of water supplies, the health impact of the investment, measured in terms of reduced diarrhoea morbidity, will continue to be restricted to those who are at low risk, and little effect will be demonstrated in the population as a whole.

The benefits to be gained from better water supplies for individuals, populations and society at large cannot be measured by morbidity from diarrhoea alone. Other health effects, changes in environmental conditions and benefits to industry, commerce, schools and housing are possible but not measurable in terms of childhood disease. However, a comprehensive approach to water supplies, with efforts to improve hygienic knowledge and practices, could also enhance these other effects.

Washing the child's hands before meals, which may possibly reflect a general knowledge of hygiene, was found here to lead to a major reduction in diarrhoea in children, and a further decrease in the risk of diarrhoea among those washing their hands before meals was noted upon use of an improved water source. Therefore, when contemplating improvements in the accessibility of water or the quality of water sources, prior evaluation of the prevailing knowledge of hygienic practices in the population (handwashing before preparing of meals, and before the meals themselves and after defecation, keeping the compound free of excreta etc.) should be the rule. After identifying the possible strengths and shortcomings of the population in this respect, a suitable local plan of action for the improvement of hygienic knowledge and practices of personal hygiene should be devised and implemented prior to the construction and improvement of water sources.

The fetching of water from a long distance away increase the occurrence of diarrhoea. Where the water source is far away from the village, an attempt to provide water nearer at hand could be reflected in a decrease in diarrhoea among the children and could also enhance other activities in the village. The information concerning the availability of water in the villages recorded here as having several households with a long journey to fetch water should be verified. Since the area is densely populated, even small investments could bring substantial benefits. Although not offering completely uncontaminated water, the protection of natural springs could form a cost-effective alternative if natural springs are present. Improvement of the availability of water at a reasonable distance may even require the technically more demanding solutions.

Since the use of surface water was found to increase the occurrence of diarrhoea, the bacteriological quality of the surface water used in the area should be examined in future research, for which technical facilities and qualified staff already exist. Health education should be directed at the avoidance of the use of surface water, which is a health hazard.

Heavy contamination with faecal coliforms was more common in natural springs than in the improved water sources, whereas the difference in the degree of contamination between shallow wells and protected springs was small. The protection of natural springs may well be of significance for improving water quality by reducing gross contamination with faecal coliforms.

As the water stored at home was frequently contaminated with enteric bacteria regardless of its source, besides improving water quality at source, hygienic aspects of water handling and transport should be emphasized alongside the improvement of water sources in order to maintain it's quality up to the time of use. Use of the traditional ceramic pots or other easily washable vessels could be encouraged, similarly, washing of the hands before collecting and handling the water, protecting the water with a lid during storage at home, and regular cleaning of the storage vessel.

Prolongation of the breastfeeding of infants and the improvement of hygiene in the preparation of weaning foods can be discussed at health education sessions in order to reduce diarrhoeal morbidity among infants and toddlers.

Assessing the results obtained in this setting, one can conclude that water was the most important vehicle of enteric infection probably only in limited cases. On the other hand, if adequately used, even slightly polluted water can substantially reduce the risk of infection caused by dirty hands and deficiencies in general hygiene. The focus of investments in water schemes should therefore be on the use of water and on hygiene in addition to the construction of water supplies. This enlargement of the scope might also increase the other benefits of such schemes not measurable in terms of childhood disease.

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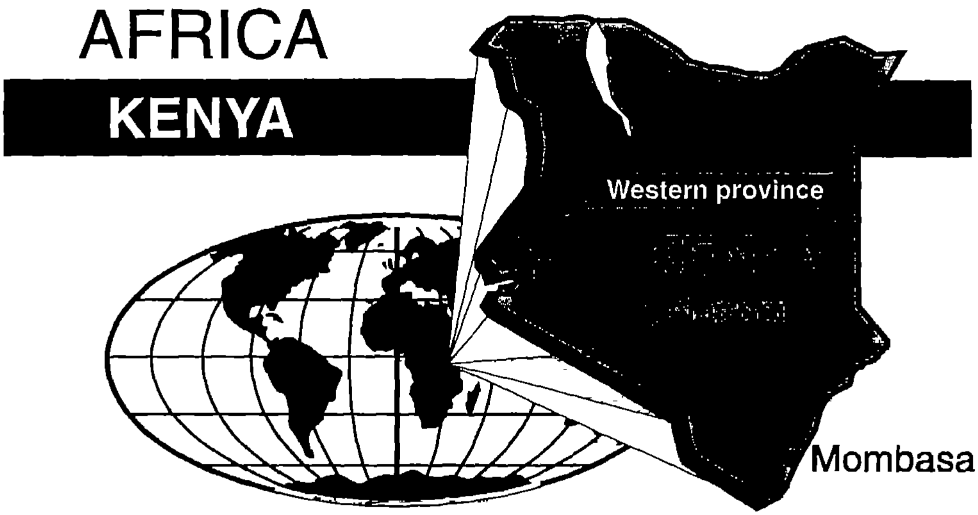
APPENDICES

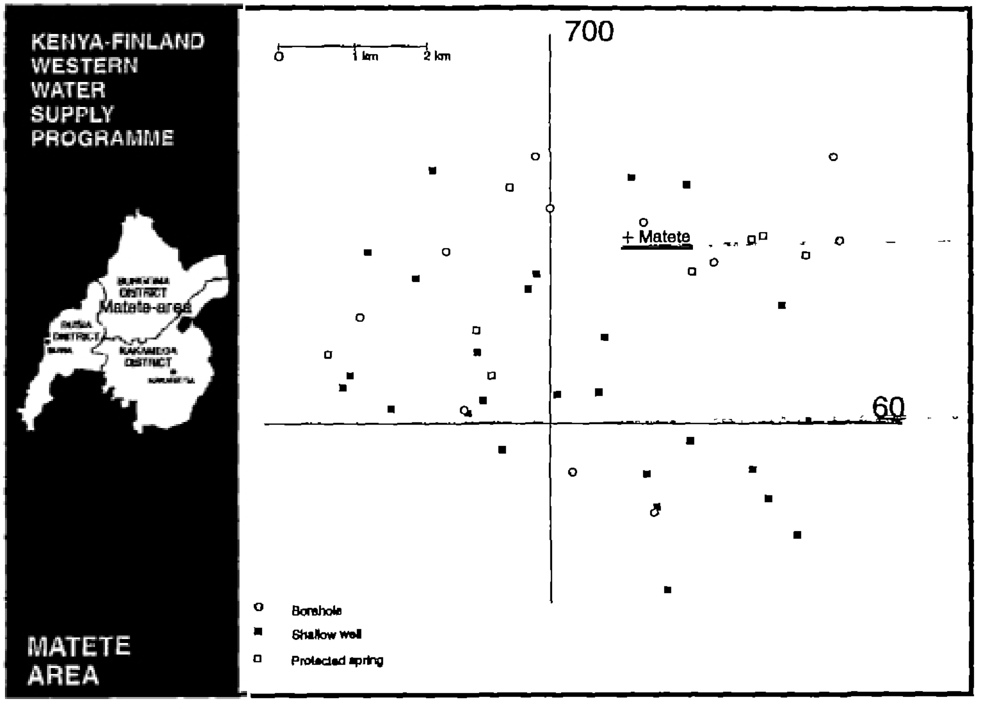
APPENDIX 1. 1/3

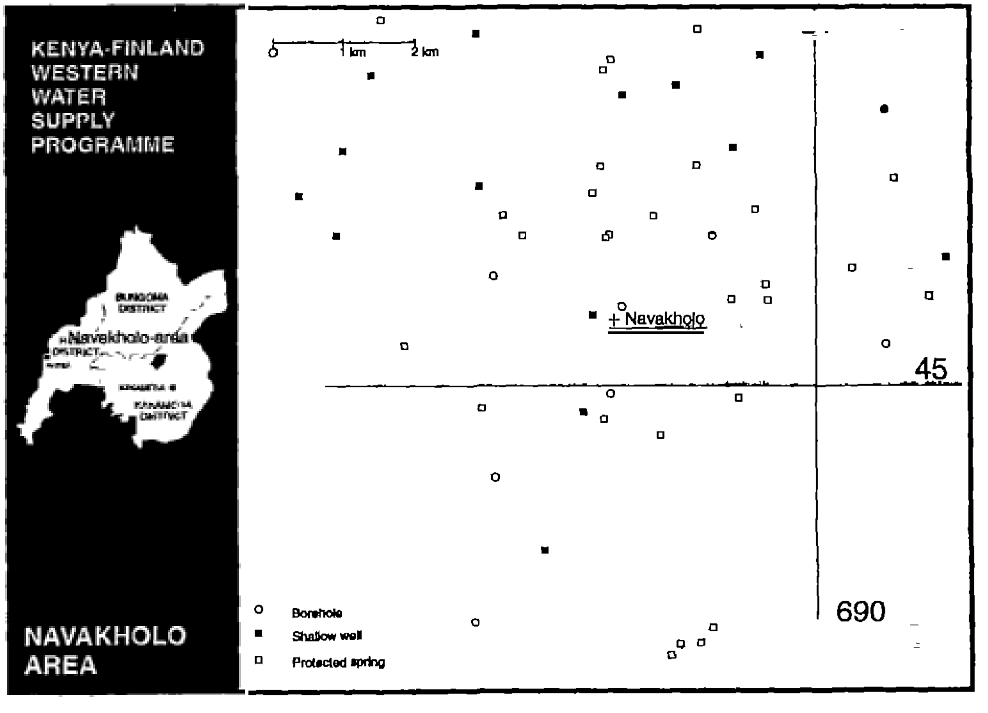


WESTERN PROVINCE OF KENYA

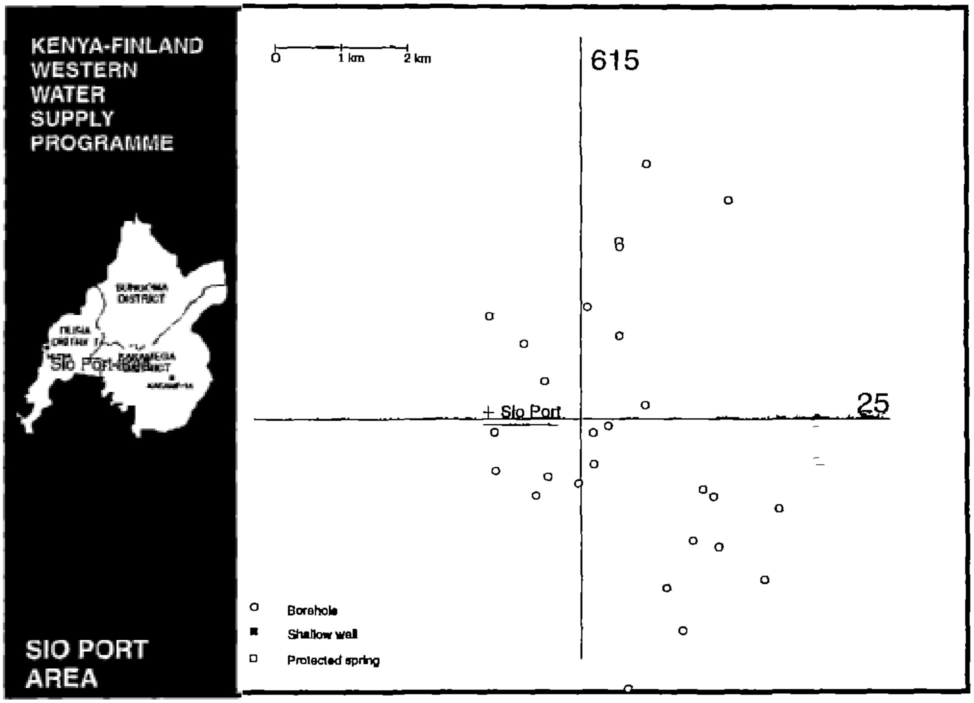
Juhani Rasila

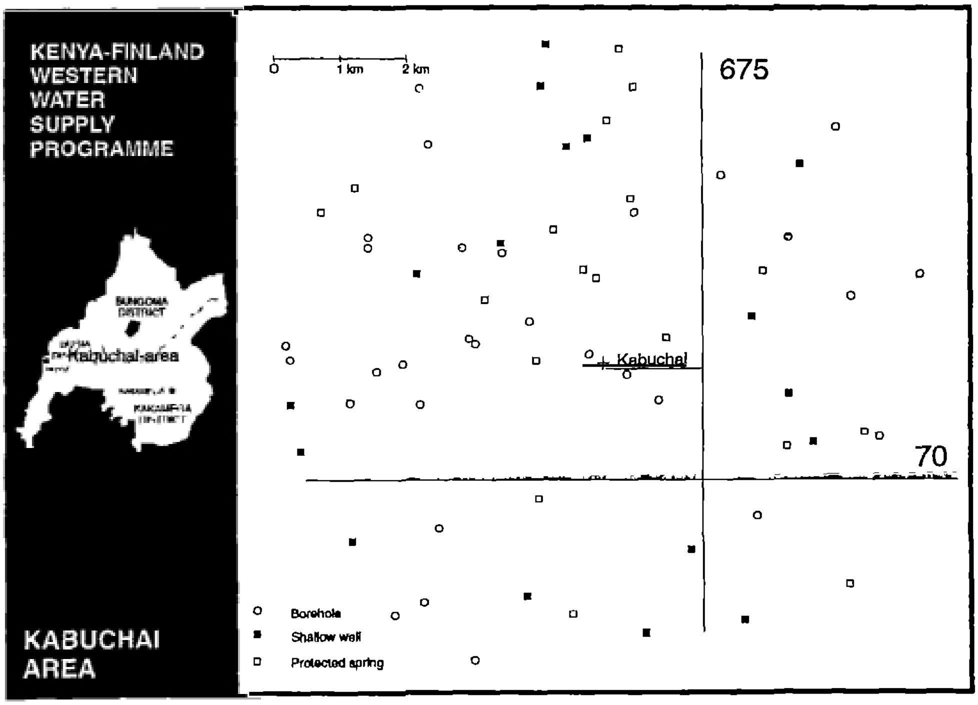
APPENDIX 1. 2/3





APPENDIX 1. 3/3





APPENDIX 2. 1/3

WATER SUPPLY AND DIARRHOEAL DISEASES IN WESTERN PROVINCE, KENYA

IDENTIFICATION NUMBER: ____________________

1. Case (Diarrhoea) (1) or
   Control (Acute Respiratory Infection) (0)

2. Name: ____________________________

3. Sex: Male (1)   Female (2)

4. Age: ____ Years ____ Months

5. Weight (Kg): ________________________

6. Height (cm): ________________________

7. Child feeding:
   Breast (1), Weaning (2), Breast & Weaning (3),
   Normal food (4), Unknown (9)

8. Number of children under 15 years belonging to the same mother:

9. Mother's education:

   Education codes: 0 = Illiterate
   1 = Some Primary School
   2 = Primary school completed
   3 = Some secondary school
   4 = Secondary school or more completed
   9 = Unknown

10. Mother's age (years):

11. How many persons live in the household:

12. Location:

13. Sub-location:

14. Village:

15. Health centre:

    Codes: 1 = Navakholo
    2 = Matete
    3 = Sio-Port
    4 = Hamisi
    5 = Kabuchai
    6 = Ipali

APPENDIX 2. 2/3

*

Which water sources are used by the household?
Water point number (if any)

16. Drinking water:

17. Cooking water:

18. Washing water:

19. Garden watering:

20. Animal drinking water:

Water source codes:
1 = River/stream
2 = Rain/roof catchment
3 = Pond
4 = Spring, natural
5 = Spring, protected (has number)
6 = Hand dug well (has number)
7 = Borehole (has number)
8 = Piped water from public taps/kiosks
9 = Unknown

21. Distance to drinking water source (metres):

22. Distance to cooking water source (meter):

23. Distance to washing water source (meter):

24. Distance to garden water source (metres):

25. Distance to animal drinking water source (metres):

Quantity of water collected in a day?

Description of collecting vessel

Volume of vessel (litres)

Number of vessels collected per day

26. Total amount of water collected (litres):

27. Vessel used for storing water in the house:

Codes: 1 = Pot
2 = Jerry can
3 = Pail
4 = Other

APPENDIX 2. 3/3

28. How often is the storage vessel cleaned:
Codes: 1 = Daily
2 = Weekly
3 = Monthly
4 = Yearly
5 = Never
6 = Unknown

29. Latrine in the home or compound:
None (0), Traditional pit latrine (1), Ventilated pit latrine (2), WC (3)

30. Latrine used by mother Yes (1) No (0)

31. Where does the child usually defecate:
Codes: 1 = Latrine
2 = Behind the house
3 = Garden
4 = Road/street
5 = Cow's place
6 = Other
9 = Unknown

32.
If the child is 1-11 months old:
Does the mother wash her hands before feeding the child? Yes (1) No (0)

If the child is aged 12 months or more:
Are the child's hands washed before eating?
Yes (1) No (0)

33.
If the child is 1-11 months old:
Hygicult cultivation from the mothers's hand

(slide No. _________)

If the child is aged 12 months or more:
Hygicult cultivation from the child's hand

(slide No.)

34. Hygicult examination of water stored in the house

Date ______/_____/19__

33 - 34 hygicult examination codes:
0 = Negative
1 = Low positive
2 = Positive
3 = High positive
9 = Unknown

Date of interview: ______/_____/19__

Signatures of interviewers: ______________________

APPENDIX 3. 1/3

Distribution of certain variables among the diarrhoea and control children

Variable	Diarrhoea group (n 502) %	ARI group (n 627) %
Males	51	53
Age of the child		
0-6 months	24	32
7-11 months	28	22
12-23 months	34	22
24-50 months	14	24
Age of the mother		
15-19y	14	14
20-24	43	36
25-29	23	24
30-34	12	14
35-50	8	12
Number of children (<15y) belonging to the mother		
1	28	25
2	25	23
3	17	18
4	17	14
5 or more	14	20
Household members		
2	-	-
3	16	15
4	21	20
5	19	15
6 or more	44	50
no data	-	-

APPENDIX 3. 2/3

Variable	Diarrhoea group (n 502) %	ARI group (n 627) %
Education of the mother		
illiterate	12	16
some primary school	44	38
primary completed	22	23
some secondary school	14	14
secondary completed	8	9
no data	-	-
Feeding of the child		
breast	7	14
weaning	70	56
adult food	23	30
no data	-	0
Source of drinking water		
roof catchment	-	-
protected spring	29	34
shallow well	8	8
borehole	14	17
piped water	4	3
river, lake	11	7
pond pool, dam	7	4
unprotected spring	27	27
Quantity of water collected/ person/day		
=<20 l	77	76
>21 l	23	24
Distance from water source		
=<100 m	14	15
101-500 m	55	60
>500 m	31	25

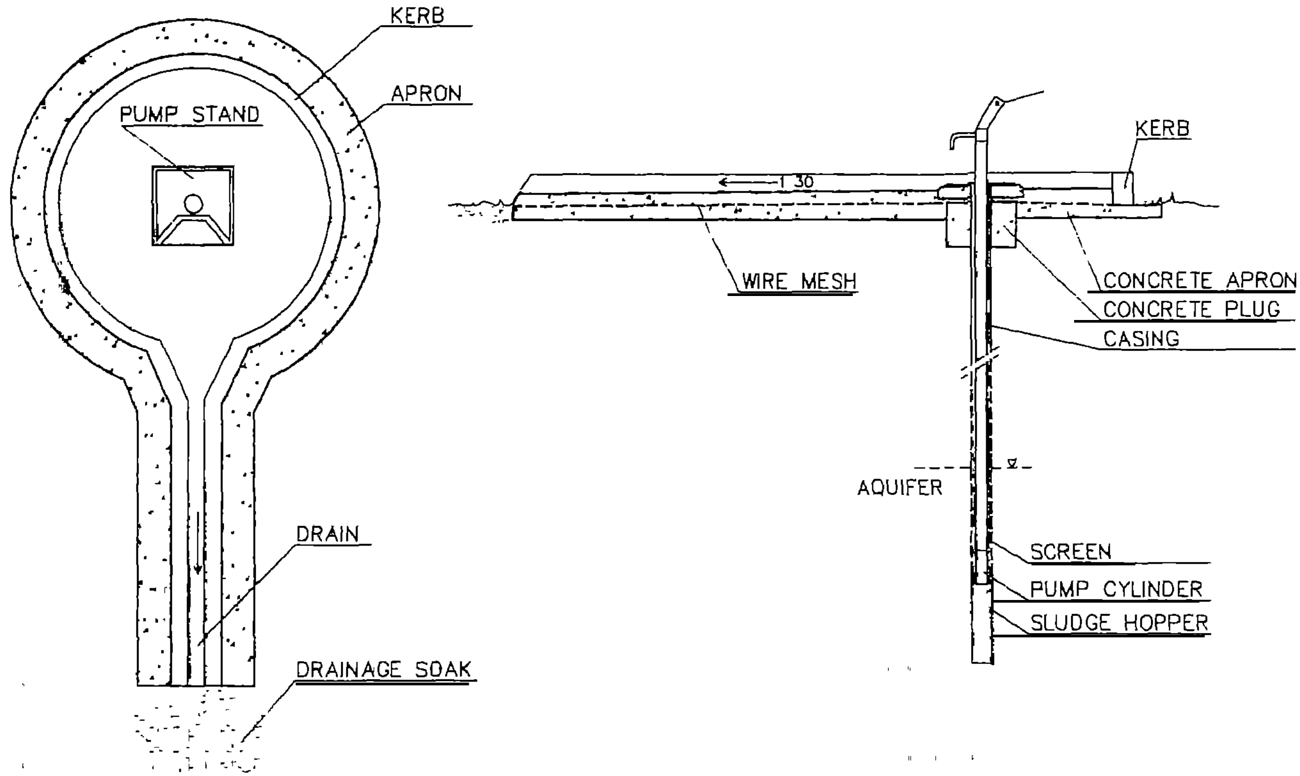
APPENDIX 3. 3/3

Variable	Diarrhoea group (n 502) %	ARI group (n 627) %
Water storage vessel		
clay pot	93	93
jerry can	6	5
other	1	2
no data	0	-
Cleaning of water storage vessel		
daily	24	20
weekly	74	79
less frequently	1	-
no data	1	1
Latrine in the household		
pit latrine	95	95
VIP latrine	-	-
flush toilet	-	-
no latrine	5	5
no data	-	-
Mother uses latrine	93	92
Child's defecation place		
latrine	4	8
behind the house or in the garden	26	28
other	70	63
no data	-	-
Mother washes her hands befor feeding the infant (1-11m)	13	14
Child's hands (1-5 y) washed before meal	70	86

- = < 1

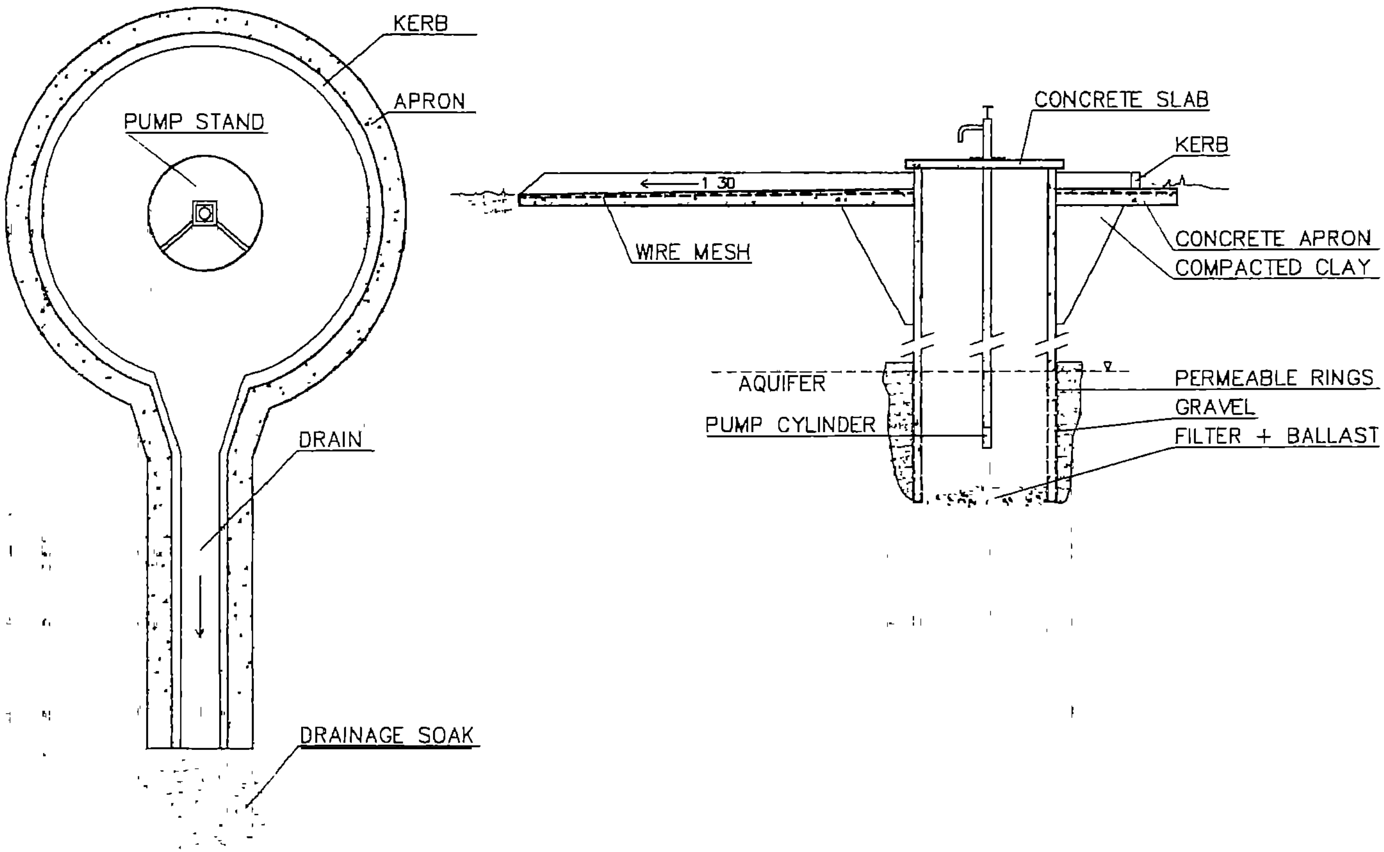
BORE HOLE WELL WITH HAND PUMP

NOT IN SCALE



SHALLOW WELL WITH HAND PUMP

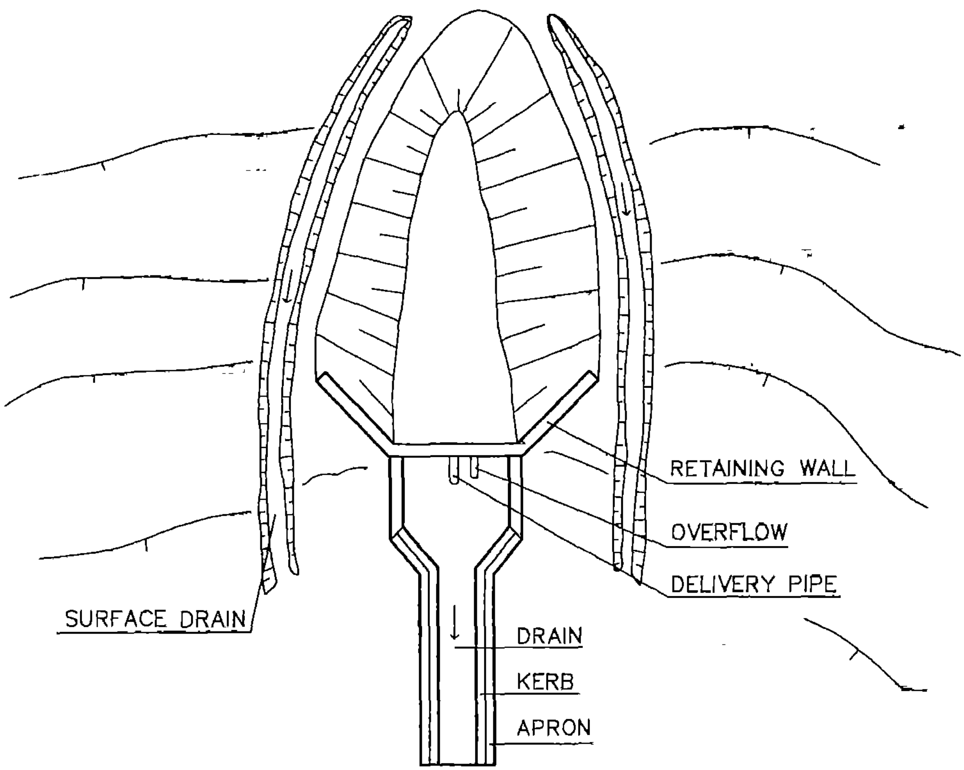
NOT IN SCALE

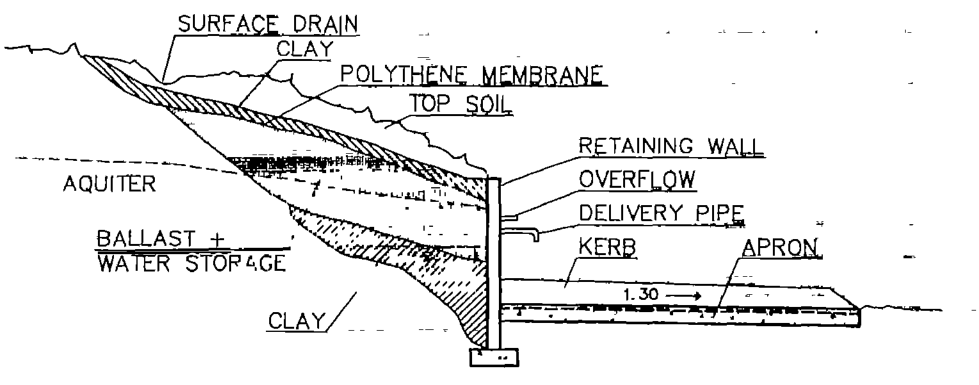


APPENDIX 4. 3/3

PROTECTED SPRING

NOT IN SCALE





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