Childhood diarrhoea and its prevention in Nicaragua

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Chapter 1

Introduction, description of the study site

Villa Carlos Fonseca

Chapter 1

Introduction, description of the study site Villa Carlos Fonseca

Introduction

Diarrhoeal diseases in developing countries are still amongst the leading causes of childhood morbidity and mortality, although their importance has been declining steadily during the last decades as a resultant of improved living conditions, better treatment protocols and a changing pattern of disease morbidity and mortality^{1,2}. When the same living conditions of poverty, inadequate water supplies, poor sanitation and hygiene, and limited education were present in the United States and Western Europe more than half a century ago, the problems with diarrhoeal diseases were similar. With economic development these conditions improved and problems with diarrhoeal diseases greatly diminished^{2,3}.

Nicaragua is developing in many aspects, but diarrhoeal disease is still an important cause of childhood death. In the early 1980's when our research started it was the leading cause (40%) of infant mortality, with about 30 deaths per 1,000 live births during the first year of life⁴. At that time no diarrhoeal research had taken place in Nicaragua and what was known was inferred from studies in other countries.

In this thesis I describe our studies and their results. The research started in 1986, with a small team, and the intention of performing only one investigation. Over time more researchers became involved and follow-up studies were designed. It became an integral programme of diarrhoeal disease research and central to it the utilization of the results in health promotion programmes. The programme was performed in collaboration with the Nicaraguan Water Institute, the Nicaraguan Ministry of Health, the Technical University of Managua, the Public Health Institute of Managua, the Nicaraguan Foundation DESEAR, the Central American Institute of Health ICAS, the London School of Hygiene and Tropical Medicine and the Liverpool School of Tropical Medicine. It was financed by the WHO, the Leverhulme Trust, UNICEF and the British Embassy in Nicaragua.

Chapter 1 introduces the investigations of diarrhoea, water supplies, sanitation, hygiene and health beliefs, and also the study site Villa Carlos Fonseca, a rural health area, where I worked as a medical officer from 1983 to 1986 and kept on living during the research. Chapter 2 contains an introduction on infant morbidity and mortality in developing countries as well as on diarrhoeal disease. Chapter 3 is an updated version of an earlier literature review of the health impact of improved water supplies/sanitation and hygiene on the incidence of diarrhoeal disease.

Chapter 4 presents the water supplies/sanitation/hygiene and health beliefs studies that we performed in Villa Carlos Fonseca. When we started our research the use of case-control studies to investigate risk factors for acute illnesses such as diarrhoeal diseases was strongly advocated by the Diarrhoeal Diseases Control Programme of the World Health Organisation (WHO). The WHO stimulated this development by the publication of guidelines of how to conduct such a study⁵ and by financing them, including our investigation^a. As part of the study we investigated the microbiological quality of water of traditional sources^b and the quantity of water used by the households^c.

The results supported the notion that not the quality of water, but the availability of water was an important risk factor for diarrhoea. They suggest that the transmission of diarrhoea in Nicaragua is predominantly water-washed rather than water-borne. Maternal schooling reduced the risk to acquire diarrhoea, possibly an indicator of better hygiene practices. This was supported by the correlation found between per capita domestic water consumption and maternal schooling. A follow-up study was then performed to investigate the relation between mother's education, the different hygiene practices and diarrhoeal diseases^d.

The Villa Carlos Fonseca Studies:

- 1986 *Investigation of the microbiological water quality of traditional water sources and of the quantity of water used by the households*
- 1986 *Case control study of the relation of water supply and sanitation with diarrhoeal disease*
- 1989 *Prospective follow-up study of the relationship between hygiene behaviour and diarrhoeal disease*
- 1989 *Ethnographic study of traditional health beliefs and practices on diarrhoeal disease*
- 1990 *Morbidity-mortality survey of a random sample of the population, with special attention to diarrhoeal disease and traditional health beliefs and practices.*
- 1992 *Literature review of the health impact of water supplies, sanitation and hygiene on the incidence of diarrhoeal disease and to identify which interventions are most likely to reduce faecal contamination of wells, waterholes and surface water*
- 1992 *A randomized trial of the impact of rope-pumps on water quality*
- 1997 *Update of the 1992 literature review*

^a Gortler A, Sandiford P, Davey Smith G and Pauw J, Water supply sanitation and diarrhoeal disease in Nicaragua: Results from a case-control study. *International Journal of Epidemiology* 1991; 20:527-533.

^b Sandiford P, Gortler A, Davey Smith G and Pauw J, Determinants of drinking water quality in rural Nicaragua. *Epidemiology and Infection* 1989; 102:429-438.

^c Sandiford P, Gortler A, Orozco G and Pauw J, Determinants of domestic water use in rural Nicaragua. *Journal of Tropical Medicine and Hygiene* 1990; 93:383-389.

^d Gortler AC, Sandiford P, Pauw J, Morales P, Pérez RM and Alberts H, Hygiene behaviour in rural Nicaragua in relation to diarrhoea. To be published by *International Journal of Epidemiology*, 1998.

Although in 1989 the mortality due to diarrhoeal diseases was declining the disease was still the leading cause of infant mortality in Nicaragua. One of the possible reasons, in addition to the continuing high incidence of diarrhoea, was the late arrival of children with severe dehydration at the health services⁶. To investigate why prevention measures such as the implementation of water supplies, sanitation and hygiene education have had limited results and why some mothers were reluctant to use oral rehydration fluids and/or bring their children to the nearby health service facilities, an ethnographic study of traditional health beliefs and practices was undertaken. A year later we performed a survey of morbidity/mortality and health service utilization. An important part of this study was directed towards quantifying the results of the ethnographic study and determining the importance of local beliefs on the management of cases of diarrhoea⁷.

Chapter 5 is an updated version of an earlier literature review to identify which interventions are most likely to reduce faecal contamination of wells, waterholes and surface water. To improve access to water a programme started to develop an appropriate water lifting device for hand-dug wells; the type of water source most frequently used in Villa Carlos Fonseca and other rural areas of Nicaragua. The programme developed a rustic version of the rope-pump into an appropriate technology, highly efficient, cheap and easy to maintain (appendix f). The National Water Institute of Nicaragua nowadays considers this improved rope-pump as the most appropriate pump for the hand-dug and tube wells of the rural areas and the pump has been introduced in other developing countries of Latin America, Africa and Asia. Given the success of this technology we felt it opportune to investigate the effect of rope-pumps on the microbiological quality of water and on the quantity of water used by the households and a study was undertaken to evaluate these effects⁸, of which the results are described in Chapter 6.

Chapter 7 discusses the relevance of the Villa Carlos Fonseca studies. The appendix contains the article on rope-pumps and an article we wrote about the decline of childhood mortality in Nicaragua⁹.

Description of the study site Villa Carlos Fonseca

Nicaragua is the largest country in Central America. Since 1900 the population has grown explosively from 500,000 in 1906, to 1,000,000 in 1950, to 4,360,000 inhabitants in 1995⁷. The fertility rate has decreased slowly from 6.9 births per woman in 1970 to 4.1 in 1995^{3,8}.

e Gorter AC, Sánchez G, Pauw J, Pérez RM, Sandiford P and Davey Smith G, Diarrea infantil en la Nicaragua rural: creencias y prácticas de salud tradicional. *Boletín de la Oficina Sanitaria Panamericana*, 1995; 119:377-390.

f Sandiford P, Alberts H, Orozco JG and Gorter A, The Nicaraguan Rope Pump. *Waterlines* 1993; 11:27-30.

g Gorter AC, Alberts JH, Gago JF and Sandiford P, A randomized trial of the impact of rope-pumps on water quality. *Journal of Tropical Medicine and Hygiene* 1995; 98:247-255.

h Sandiford P, Morales P, Gorter A, Coyle E and Davey Smith G, Why do child mortality rates fall? An analysis of the Nicaraguan Experience. *American Journal of Public Health* 1991; 81:30-37.

Nicaragua has a low-income economy and ranks 30th on the list of poorest countries of the world. It is the poorest country of Central America; yet it has a surprisingly low infant mortality rate (46 per 1,000 live births); low prevalence of malnutrition under-5-years (12%); a high enrolment in primary and secondary school; and a relatively low adult illiteracy (26%)⁶. After several decades of political turmoil, revolution and war it has now a relatively stable democracy.

The country consists of three distinct geographical regions: the Pacific lowlands, the north-central mountains, and the Caribbean lowlands. Villa Carlos Fonseca, where our research takes place, is situated in the Pacific coastal region, a broad and hot lowland plain, broken by about 40 volcanoes. It is a rural municipality within the department of Managua at a distance of 30 km from Managua, the capital of Nicaragua. Within its area of 500 square kilometres there are approximately 32,000 inhabitants distributed amongst 38 communities (see map). There is one health centre, a small laboratory, and 6 smaller health posts, all poorly equipped and without running water. As referred to earlier, for over 3 years I worked as a Medical Officer in this health area. The daily routine concerned the medical consulting-hour; the organization of the many disease control programmes such as those of tuberculosis, malaria and sexually transmitted diseases; the training of personnel and traditional midwives and the organization of vaccination campaigns. Each doctor participated in the night or weekend shifts of a small hospital near our health area, which also served the population of our health area.

The conditions observed most frequently during the consulting-hour consisted of diarrhoeal disease with or without dehydration, respiratory infections, worms and skin diseases in children. Women generally consulted the doctor for prenatal control or family planning, although mental problems were seen frequently as well. Men rarely consulted a doctor and if so, it concerned almost always a serious condition. During the years I worked in this health area, the medical staff consisted of only 2 or 3 doctors. Nowadays the area counts 8 to 10 doctors, mostly trained in Nicaragua, although one has been trained in Russia.

The 38 rural communities are connected through one asphalt main road and many small tracks generally in bad condition. Illiteracy is 29% which is high compared to the capital Managua (9%), but low when compared with the national figure of 43% of illiteracy for the rural site⁷.

The last national population census in Nicaragua took place in 1995. Data were published recently⁷. The report presents data from the rural area of the department Managua, of which Villa Carlos Fonseca is a part. Living conditions are still poor for that area with 10% of families living in nothing more than a hut, although this number was much higher in a census of 1963 (40%). On average a house has 1.9 rooms and 5 persons living in it with an average of 3.4 people sleeping in one room. Of the houses 63% has electricity.

In the census people were also asked about their daily activities and 47% of the population answered to be economically active. Of this group 21% were looking for work at the

From: van Klinken PC, *Cholera preventie in Nicaragua. Een onderzoek naar de kennis, attituden en praktijken ten aanzien van cholera en cholera preventie. Cholera prevention in Nicaragua (A study of the knowledge, attitudes and practices concerning cholera and cholera prevention). Thesis Health Education, Department of Health Education, University of Maastricht, 1993*

moment of the interview, thus in reality unemployed; 33% were working in agriculture; 10% in industry; 4% did not specify and 32% were active in the "service" sector of which the majority is working in the informal sector. This sector has become economically the most important one, especially in the city of Managua where 71% of the economically active people is working in this so called "service" sector.

Villa Carlos Fonseca has been a tropical dry zone for the last decades, characterized by many lost harvests as a result of the increasing deforestation⁹ and the changing weather pattern, related to the Warm Gulf Stream 'El Niño'¹⁰. Many agricultural activities are not profitable anymore, especially those of the subsistence farmers who have no irrigation systems and thus are dependent on the annual rains. The most important crop cultivated now is sugarcane, grown with irrigation. There are two small factories which process sugarcane; one produces sugar and the other alcohol. These factories are the only industry of the area.

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Chapter 2

Infant morbidity and mortality, diarrhoeal diseases

Chapter 2

Infant morbidity and mortality, diarrhoeal diseases

Infant morbidity and mortality

Health conditions around the world have improved more in the past forty years than in all previous human history. Infant mortality in developed countries started to decline about two centuries ago, at first slowly. The rate of improvement accelerated in the first half of this century^{1,2}. Several decades later this phenomenon was also seen in developing countries. For the Latin American countries the decline started around the turn of the century in the relatively highly developed countries of this continent and around 1930 for the less developed countries³. For Africa the decline started after World War II⁴. The decline in developing countries has accelerated over the past thirty years; in the 1960's infant mortality fell by approximately 2% a year; in the 1970's by more than 3% and in the 1980's by more than 5% a year¹.

Table 1 shows figures for the last 25 years, during which infant mortality (under-1-year) has fallen sharply over a relative short period; almost to a half of the mortality of 1970^{1,5}. Overall mortality of under-5-years in the developing countries has fallen as well; from 152 (per 1,000 life births) in 1975 to 80 in 1996, with nowadays a total of about 1.1 million children dying each year before they reach the age of 5^{1,6,35}. For the developed countries the under-5-year mortality declined from 25 to 7 per 1,000 life births.

There are strong parallels between the pattern of mortality decline in the developed countries and the accelerated progress of developing countries over the past 40 years. In both groups the control of communicable diseases, particularly those of childhood, accounts for most of the gains¹. Part of this reduction has been explained by the declining mortality due to diarrhoeal diseases.

Diarrhoea related mortality has constantly been decreasing since the introduction, early 1978, of the treatment of dehydration (which plays a substantial role in case fatality) with oral fluid and electrolyte replacement. This oral rehydration therapy, shortly called ORT, became the cornerstone of the child survival programmes of UNICEF and WHO². During the period 1981- 1986 diarrhoea was estimated as the cause in 36% of all deaths in under-fives⁷. Nowadays diarrhoea is responsible for only about 25% of deaths among under-5-years in developing countries⁸.

Of the estimated billion episodes of diarrhoea which occur each year in under-5-years 3 million cause death^{6,9}. In the first year of life around 20 diarrhoeal deaths per 1,000 children occur, meanwhile in the 1- to 4- year age group the rate is much lower with

5 deaths per 1,000, although these still account for half of the diarrhoeal deaths in childhood⁹. After the first 5 years of life mortality rates appear to fall to very low levels and increase later slightly in the elderly^{2,9}.

Table 1. Infant mortality figures (World Bank Report 1993 and 1997)

Economies	Infant mortality rate per 1,000 live births	
	1970	1995
Low income economies	109	69
Lower-middle-income	87	41
Upper-middle-income	72	35
High-income	20	7
World	85	55

Continents	Infant mortality rate per 1,000 live births	
	1970	1995
Sub-Saharan Africa	144	92
South Asia	138	75
India	137	68
Middle East & North Africa	135	54
Latin America & Caribbean	82	37
East Asia & Pacific	76	40
China	69	34
Europe and Central Asia	63	26

Central America	Infant mortality rate per 1,000 live births	
	1970	1995
Nicaragua	106	46
Honduras	110	45
Guatemala	100	44
El Salvador	103	36
Costa Rica	62	13

The World Bank, jointly with the World Health Organisation (WHO), developed a method to measure the global burden of disease (GBD), combining:

- healthy life years lost because of premature mortality, defined as the difference between actual age at death and life expectancy at that age in a low-mortality population,
- loss of healthy life resulting from disability.

The GBD is measured in units of disability-adjusted life years (DALYs). Worldwide 1,360 millions DALYs were lost in 1990, the equivalent of 42 million deaths of newborn children. There is a huge variation in loss of DALYs across regions, mainly because of differences in premature mortality and much less because of differences in disability¹.

In its report of 1993 the World Bank concluded that diarrhoeal diseases are now the second, after respiratory infections, most important cause of disability-adjusted life years lost¹. Where diarrhoeal diseases have been the leading cause of childhood mortality for centuries, during the last decades together with the declining overall childhood mortality, a changing pattern is observed towards respiratory infections as being now the most important single cause of death for children in developing countries.

Nicaragua does not make an exception and has experienced even a more impressive decline relatively to its national income, like some other low income countries did such as China and Sri Lanka¹. Infant mortality in Nicaragua has decreased from 106 per 1,000 live births in 1970 to 44 in 1996^{1,5,35}. In 1990, the Ministry of Health reported diarrhoeal disease still as the most important single cause of death and responsible for 40% of infant mortality and for 33% of deaths in children of 1 to 4 years old¹⁰, although a study in the north of the country showed that the prevalence of diarrhoea was lower than that of respiratory infections in under-5-years¹¹.

The decline of childhood mortality in Nicaragua and its possible reasons have been investigated by our study team and described in an article in the *American Journal of Public Health* of 1991 (appendix).

Diarrhoeal diseases

Definition

Diarrhoea is a symptom complex characterized by stools of decreased consistency and increased number. Most studies now consider diarrhoea to be present when 3 or 4 or more liquid stools are passed during any 24-hour period. Generally at least 2 days free of diarrhoea are required to determine that an episode is finished. A WHO meeting recommended that the small proportion of diarrhoea episodes which last 2 or more weeks should be defined as persistent diarrhoea^{2,12}.

Morbidity and mortality

Figures based on 7,350 cross-sectional surveys in 70 countries show a global medium of 3.4 episodes per child under 5 years, ranging from 1 to 5 illnesses per year per child in developed countries to 5 to 12 illnesses per year per child in developing countries to as many as 18 in children living in impoverished areas of these countries^{7,13}. The incidence is highest in children under 2 years of age, followed by a progressive fall with age². The peak incidence is in children from 6 to 11 months^{2,14,15}.

The majority of diarrhoeal episodes resolves within 1 week. A small fraction takes up to 2 weeks and persistent diarrhoea has been found in a range from 3 to 23% of all episodes, persistent diarrhoea being more frequent when overall diarrhoea incidence is higher². The study in the north of Nicaragua found a range of persistent diarrhoea of 4 to 7% of all episodes and a higher case fatality during the wet period when diarrhoea incidence in Nicaragua is highest¹¹.

The case fatality rate in children under 5 years of age has been reported to be between 0.1% and 0.7%, and for persistent diarrhoea a rate of 14% has been published. Case fatality rates vary with age, and are highest among infants under 1 year^{2,9}. About 50% of diarrhoeal deaths are due to acute watery diarrhoea, 35% to persistent diarrhoea, and 15% to dysentery⁶.

Pathogens

The causes of diarrhoea include a wide array of viruses, bacteria, and parasites, many of which have been recognized only in the last decade or two. There are several viruses detected to cause diarrhoea: rotavirus, enteric adenovirus, a growing family of *Norwalk* like virus, possibly coronavirus and others^{2,16}.

Bacteria which cause diarrhoea are: enterotoxigenic *Escherichia coli* (ETEC), *Campylobacter* species, *Shigella*, *Salmonella*, *Vibrio cholerae*, the enteroadherent *Escherichia coli* (EAEC) designated as: aggregative (EAEC-AA); diffuse-adhering (EAEC-DA) and localized-adhering (EAEC-LA), furthermore the enterohemorrhagic *Escherichia coli* (O157:H7), possibly cytotoxigenic *Clostridium difficile*, *Aeromonas hydrophila*, *Yersinia enterocolitica*, *Listeria monocytogenes*, and others^{2,17,18}.

Parasites known to cause diarrhoea are: *Giardia lamblia*, *Entamoeba histolytica*, *Cryptosporidium parvum*, *Isospora belli*, *Sarcocystis* species, *Microsporidia*, *Cyclospora* species, *Balantidium coli*, *Chilomastix mesnili*, and intestinal helminthic infections such as *Trichuris trichiura*, *Strongyloides stercoralis*, *Necator americanus*, *Ancylostoma duodenale*, *Capillaria philippinensis* and *Trichostrongylus* species^{2,19}.

The frequencies of the enteropathogens causing diarrhoea vary in different countries, especially between those of the developed and developing world. In the developing countries ETEC and rotavirus predominate^{2,20}. *Norwalk* like virus, *Campylobacter* and *Clostridium difficile*, and lately also *E.Coli* O157:H7, have been described as a frequent cause of bloody diarrhoea in the developed world^{21,22,23}. *Shigella*, *Salmonella*, *Cryptosporidium* and *Giardia* are found throughout the world¹³.

Two types of etiology studies have been performed in the developing countries; **hospital-based studies** where the faecal specimens are collected in the health facilities; either outpatient clinics or hospital wards, and **community-based studies** where the faecal specimens for culture are collected during household visits. Results from these last studies represent the overall occurrence and etiology of diarrhoeal illnesses best, regardless of the severity of the diarrhoea or care-seeking. The hospital-based studies reflect the etiology of the more severe cases and those which cause a high mortality.

Based on 18 community studies with comprehensive microbiology from 9 developing countries (of the three continents Asia, Africa and Latin-America) ETEC was found to constitute the largest proportion of episodes with a median of 14%. The next most commonly found was *Giardia lamblia*, although the proportion infected has been highly variable. *Campylobacter* species have been isolated from a median of 7%, rotaviruses from 5%

and *Shigella* species from 4%, *Cryptosporidium parvum* was found in 2% to 7% of episodes and *Entamoeba histolytica* in 2% or less².

In a community-based study performed in the north of Nicaragua in 1990 (before the cholera epidemic) faecal specimens of 188 children under 5 years who had diarrhoea at the moment of the household visit were investigated. *Giardia lamblia* was found to be the pathogen most frequently seen, followed by *Escherichia coli* (ETEC and EAEC-LA) and rotavirus, then *Entamoeba histolytica* and finally one case of *Shigella*. No *Salmonella*, or *Campylobacter* were found¹¹.

In 52 hospital-based studies with comprehensive microbiology in 29 developing countries (also in the three continents), rotavirus was the pathogen most frequently seen with a median of 20%, although overall the bacterial enteropathogens predominate; ETEC with a median of 12%, *Campylobacter* species with 7% and *Shigella* species with 5%. *Aeromonas*, *Salmonella* species and vibrios, especially *Vibrio cholerae*, may be frequent in some settings. In the latest 9 studies seeking for *Cryptosporidium parvum* it was found with a median of 5%. *Giardia lamblia* has been found infrequently and *Entamoeba histolytica* rarely in the faecal specimens of children with diarrhoea of the hospital-based studies².

Important bacterial causes in the first 2 years of life are ETEC, *Shigella* and *Campylobacter*. The most common parasitic causative agent is *Cryptosporidium*. *Entamoeba histolytica* is an uncommon cause of diarrhoea in the first 2 years. *Giardia lamblia* is commonly isolated in cases, but is usually not the responsible pathogen. *Vibrio cholerae* O1 can account for as many as 5-10% of hospital cases in all ages in endemic zones, but is rarely found in children younger than 2 years²⁴. Rotavirus is the most common viral agent and is the major cause of severe dehydrating diarrhoea in the first 2 years of life in both developing and developed countries and accounts for 20-40% of diarrhoea cases requiring hospitalization in many developing countries^{2,24,25}. The greater frequency of isolation of this agent in cases of diarrhoea in health facilities studies compared to the community studies reflects the greater severity of the disease².

Pathogens found in the stools of diarrhoeal cases of case-control studies are also well represented in controls, indicating an important amount of asymptomatic infections of these pathogens, with *Shigella* and rotavirus the notable exceptions^{26,27,28}. *Giardia* was found in 100% of Egyptian children of 2-4 year old whose stools were examined during 6 months²⁹. In fact, studies frequently find two or more enteropathogens simultaneously and it is rarely possible to ascertain which is causing the illness or if they are playing a role each. The high prevalence of asymptomatic infections is probably more an indicator of frequent exposure to a commonly existing pathogen than a long-term carrier state, which seems to be rare².

The etiology of persistent diarrhoea (diarrhoea which last 2 or more weeks), which probably accounts for about 35% of deaths, remains unclear. Multiple bacterial and viral pathogens are often found as well as frequent colonization of the small intestine with co-

lifform (or other) bacteria, which have been shown to cause prolonged diarrhoea in an animal model^{13,30}. In several studies *Shigella*, EAEC-AA, and EAEC-DA^{2,25,31} have been found more frequently in persistent than in acute diarrhoea. ETEC, *Campylobacter*, *Aeromonas* species, *Giardia lamblia* and *Entamoeba histolytica* have similar rates. Meanwhile rotavirus was seen less in persistent than in acute diarrhoea^{2,27}. Ongoing infection with the same organism is uncommon. A new enteropathogen is often found in the third week of diarrhoea, suggesting that the prolonged diarrhoea is due to sequential infections with different pathogens².

Infective dose and host defenses

All causes of watery diarrhoea have an imbalance in common between the amount of fluid secreted and the ability of the intestinum to reabsorb that fluid. Many cases of diarrhoea may best be considered a pathological exaggeration of what is normally a host protective response to proliferation, attachment, or invasion by enteropathogens².

An important variable in the pathogenesis of diarrhoeal diseases is the infectious dose or the inoculum required to produce symptomatic disease in normal individuals. This infective dose varies, depending on the type of pathogen and host defenses³². The infective dose for viruses is in general low; less than 100, meanwhile that of bacteria is high^{26,33}. *Shigella* is already infectious at a very small doses, about 10-1,000^{2,33}. Person-to-person transmission seems to be the dominant route for "low-inoculum" agents such as rotavirus, *Giardia*, *Cryptosporidium*, *Entamoeba histolytica* and *Shigella*. They are easily spread from person to person, whereas "high-inoculum" agents such as *Vibrio cholerae*, *Salmonella*, and ETEC are usually acquired by ingesting larger numbers of organisms via contaminated food or water².

The infectious dose is lowered when host defenses are not optimal as happens for example when gastric acidity is decreased as is seen in malnutrition and when patients already receive antibiotics².

Seasonality

Although diarrhoea occurs throughout the whole year, most settings have a peak during the hot and/or rainy months. This seasonality is a composite of the seasonality of pathogens. Most bacterial causes peak during the hot and/or wet months. Meanwhile in tropical areas rotavirus has the same prevalence during the whole year, in more temperate climates it peaks in the cool and/or dry season^{2,25,26}. A 10-year survey on shigellosis in Teknaf, Bangladesh, showed a round-the-year infection with two peaks: one in the monsoon period and the other in the winter period³⁴. In Nicaragua we saw a seasonal variation in our study with the highest incidence of diarrhoea during the rainy season. The same results were found in the study in the north of Nicaragua¹¹.

Prevention

Many risk factors which increase morbidity and mortality due to diarrhoeal diseases in developing countries have been identified:

- Increased transmission of pathogens:

- lack of water of good quality and in sufficient quantity
- lack of sanitation
- poor food hygiene
- poor personal hygiene
- poor domestic hygiene
- poor communal hygiene (neighbours, food vendors, schools, public places)
- Low host resistance
- Limited case management of diarrhoeal disease

The importance of these factors is influenced by the socio-economical, educational, cultural and demographical situation of the different countries and in that way the possibilities of prevention of diarrhoeal morbidity and mortality. Preventing diarrhoeal disease means interruption of the transmission of pathogens. The prevention of death due to diarrhoea may be obtained through the increase of the resistance of the host and the improvement of the case management of diarrhoeal disease:

- Reduction of the transmission of pathogens by improving:
 - water supplies and sanitation
 - personal and domestic hygiene
 - food hygiene
 - communal hygiene
- Increase of host resistance
 - prevention of low birth weight
 - breast feeding
 - improved weaning
 - supplementary feeding programs
 - monitoring child growth
 - immunizations (rotavirus, cholera, measles)
 - chemoprophylaxis
- Improved case management
 - promotion oral rehydration therapy
 - improving communication between mother and health personnel by taking in account local culture of health beliefs and practices
 - promotion of feeding during diarrhoeal period and recovery

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Chapter 3

Well water study, part 1

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Summary

There have been numerous health impact studies of water supply, sanitation and hygiene, although many of these studies have suffered from methodological flaws. There is however, a reasonable consensus that water quality improvements do not generally have as great an impact on health as interventions, which increase the availability of water or provide human faeces disposal facilities. Those interventions which improve hygienic behaviour at the household level and/or the community level, seem to have the greatest impact.

From the small amount of relevant literature that is available, and taking into account the studies of major water quality improvements, it would appear that a water quality intervention is more likely to have a positive health impact through reducing contamination from very high levels to moderate levels than from moderate levels to low levels. In highly contaminated environments where multiple transmission routes are acting together the health impact of improved water quality may be limited. In developing countries one should not expect more than a 10-20% reduction in diarrhoeal disease morbidity due to the improvement of the water quality. It should be noted too that such improvements are likely to be more effective where many families share a water source than where the water source is used by just one or two households. For interventions increasing the availability of water one may expect a reduction of 20-30% or more of the incidence of diarrhoea. Providing human faeces disposal facilities seems to be more effective in urban settings than in rural communities, but depends heavily on the manner in which these facilities are used. Interventions to improve the level of hygiene practices may be highly effective, but depend on the preconditions available such as mother's level of education, facilities for water and for the disposal of faeces, while social and cultural factors may have a reinforcing or restraining influence. Reductions of up to 90% in incidence of diarrhoea have been reported for the improvement of one or more hygiene practices.

A literature review of the health impact of water supplies, sanitation and hygiene on the incidence of diarrhoeal disease

1.1. The Relationship between Health and Water

Water is not only an essential element for the sustenance of human life but also a cause of much death and disease, particularly in the developing world. Most of morbidity and mortality related to water is due to the role it plays in the transmission of a variety of communicable diseases. Bradley¹ developed a classification of water-related illness based on four different transmission routes:

1. Water-borne transmission.

This occurs when water is drunk that contains pathogens, which subsequently infect the host. All water-borne diseases with the exception of Guinea worm (dracunculiasis) are faecal-oral. That is, they pass from the faeces of one host to the mouth of another.

2. Water-washed transmission.

Here water serves as a positive factor through its use for personal and domestic hygiene. Faecal-oral pathogens are washed away thus preventing person to person transmission. Skin and eye diseases are also preventable with increased availability of water for personal and domestic hygiene purposes.

3. Water-based transmission.

This occurs when certain parasitic worms such as schistosomiasis reside in water and infect their host directly through the skin.

4. Water-related insect vector transmission.

Many insect vectors such as mosquito's breed in water or bite near water (e.g. tsetse flies). By preventing breeding in water or human contact with breeding sites, this form of transmission can be controlled.

1.2. The Importance of Water-borne Transmission

Improvements in water quality will obviously have an impact on health in those cases where the transmission route is water-borne. There are several factors, which determine the importance of the water-borne transmission route.

1.2.1. Other transmission routes

Firstly, there is the relative importance of other transmission routes. Briscoe² has argued

that for diseases such as diarrhoea where there are multiple transmission routes, reducing transmission by the dominant route will not necessarily produce a corresponding reduction in the incidence rate of that disease. However, this notion was refuted by Cairncross³ who pointed out that Briscoe's case rested upon the assumption that the multiple transmission routes were operating simultaneously which is clearly not the case for any given illness episode. Nevertheless, even if an intervention which prevents 50% of water-borne transmission, reduces the number of cases from that route by the full 50%, it may have an insignificant overall effect if that route contributes only a small proportion of the total number of cases.

1.2.2. Survival of the pathogen in water

Secondly, the importance of the water-borne route also depends upon the ability of the pathogen in question to survive outside of its host. Table 1 shows the estimated time for 50% of a bacterial population to die in a stable well water supply. There is considerable variation in the survival of different pathogens in water, with some such as *Vibrio cholerae* sensitive to the level of salinity and pH⁴. Resistance to chlorine affects survival in treated water supplies and indeed, some viruses are known to be able to withstand bactericidal concentrations of chlorine.

Table 1. Survival of various pathogens in a stable well water supply

Pathogen	Survival time hours (T ₅₀)
<i>Shigella flexneri</i>	26.8
<i>Shigella sonnei</i>	24.8
<i>Shigella dysenteriae</i>	22.4
<i>Enterococcus</i>	22.0
Coliform bacteria	17.0
<i>Salmonella enteritidis</i>	16.0
<i>Vibrio cholerae</i>	7.2
<i>Salmonella typhi</i>	6.0

Source: Feachem R *et al*, 1987⁵

1.2.3. Variation in pathogenicity

Differences in pathogenicity also determine the relative importance of the water-borne route for any given aetiology. Pathogenicity of infectious agents is usually measured by the infective dose. This is the number of pathogens which when ingested, gives rise to illness in 50% of cases. In water, the concentration of pathogens tends to be rather low and therefore it may be difficult to imbibe an infective dose merely by drinking. On the other hand, if contaminated water comes in contact with food, the bacterial pathogens may breed in that medium until an infective dose is reached. The infective dose for viruses is generally less than 100⁶. Infective doses of bacteria tend to be higher⁷, but there is considerable variation between the different species. *Shigella* needs a relatively small dose (about 1000)⁶.

Briscoe and VanDerslice have pointed out in their article "All coliforms are not created equal" that pathogenicity also depends upon the familiarity of the host with the pathogen. If a certain pathogen is new for the host, illness is much more to be expected than in the case of a pathogen with which the host has become familiar and for which he has created resistance⁸.

An interesting suggestion⁹ has been put forward that reducing waterborne transmission puts evolutionary pressure on organisms tending to reduce their pathogenicity. Although Ewald has attempted to provide some empirical support for this hypothesis, which is largely based upon theoretical considerations, his success has been limited by the quality of available historical data. The traditional health impact evaluation would not, of course, measure benefits of this type.

1.2.4. Epidemiologic profile

Obviously if the importance of water-borne transmission depends upon pathogen-specific factors, then the impact of water quality improvements will vary according to the relative incidence of these different agents. However, the converse is also true, that is, the distribution of disease will depend upon the various transmission routes that are open to pathogens. Moreover, if Ewald's hypothesis is correct, control of waterborne transmission will tend to reduce the prevalence of the more virulent species as well as reducing virulence within the population of a given species of pathogens⁹.

1.2.5. Degree of water contamination

One would expect that the importance of water-borne disease transmission increases with increasing levels of faecal contamination. This is not because a higher level of contamination implies a greater probability of encountering a pathogen, but because it also implies a greater probability of imbibing a pathogenic dose of the agent.

It is important however; to point out that faecal contamination *per se* does not imply water-borne transmission of disease. Unless the faeces contain a pathogen to which the potential host is susceptible, no infection will be transmitted. There is no doubt that a large amount of faecal matter is consumed by humans without any risk of developing an illness, simply because the faeces contains no pathogens.

Even if infectious agents are present, it is possible that the potential host has already been exposed to them. There are several important implications from this point:

- Firstly, a given level of water supply contamination may have more epidemiologic significance where that water supply serves a large population than where it serves just one or two families. In the latter case, any pathogen in the water may already have been transmitted to family members through other routes.
- Secondly, apparent health impacts due to improved water availability do not necessarily imply reduced water-washed transmission. When an intervention lowers the number of families that is served by a water source, it may actually decrease water-borne transmission more than water-washed transmission because the frequency of exposure by unfamiliar pathogens and size of the susceptible population is reduced.

- Thirdly, in-house contamination of stored water may not be as significant as contamination of source water, because family members are already familiar with that specific pathogen⁸.

1.3. Evidence for the Health Impact of Water Quality, Quantity, Sanitation and Hygiene Improvements

1.3.1. Methodological issues in health impact evaluations of water supply, sanitation and hygiene interventions

The failure to demonstrate a positive health impact of several major water supply and sanitation interventions^{10,11,12,13,14} led some scientists to re-examine the methods which were being used. Water supply and sanitation interventions are expensive, politically sensitive and often serve entire communities. These peculiarities make it often impossible to use the epidemiologically rigorous randomised controlled trial design. Most studies that have been performed are therefore observational, and are frequently designed as *post hoc* evaluations. In a review of 44 published studies of the impact of water supply and sanitation facilities on diarrhoeal disease, Blum and Feachem¹⁵ identified 8 major methodological flaws. While none of the studies reviewed were entirely free from these flaws, some were much worse than others. The eight major flaws were:

1. Use of inadequate control groups
2. Comparison of one intervention site with one control site
3. Unsatisfactory control of confounding
4. Recall bias in ascertaining disease status
5. Imprecision of disease definition
6. Failure to analyze by age
7. Failure to record facility usage
8. Insufficient consideration of seasonal variation

In addition to these deficiencies in study design, the evaluation of water supply, sanitation and hygiene interventions has been hampered by the enormous cost of carrying out longitudinal studies of the size necessary to address the key issues satisfactorily. Hence, in 1976, an expert panel to the World Bank published a paper discouraging any further studies of this type¹⁶.

Nevertheless, this paper did lead investigators to look at alternative methods to carry out health impact evaluations of water supply, sanitation and hygiene interventions. Attention focused on the case-control design, mainly because it offered the promise of lower sample sizes and the ability to make retrospective evaluations of successfully functioning water supply, sanitation and hygiene programmes^{17,18}.

Since then, various risk factor studies with the case-control design have been carried out in a wide variety of settings. Case-control studies applied in the developed countries for the investigation of the relation between cases of water contamination and the occur-

rence of diarrhoea have been producing quite clear results^{19,20,21,22}. However for the developing countries^{23,24,25,26,27,28,29,30,31,32,33,34} it has to be said that results are not much more consistent than those of the earlier designs. Although it is now possible to define disease status more precisely, the advantages of the case control study in terms of sample size and statistical power are probably not as great as was initially expected. Many of the problems previously identified remain unresolved such as the difficulty in documenting exposure and the selection of an appropriate control group.

Moreover, there are two problems which observational studies will always find difficult to deal with. One is that water supplies, sanitation and 'good' hygiene practices are not allocated randomly within the study population, but tend to correlate strongly with other health-related social and economic factors. Some of these factors are very difficult to measure and hence control for during the analysis stage. A second problem is that these studies are based on an assumption that individuals behave passively with regard to the putative risk factors³⁵. In reality though, it is possible, for example, that a household with a contaminated water supply will be more likely to boil a child's drinking water than a household with an uncontaminated water supply. Unless such practices are measured and taken into account, traditional analyses will yield misleading results³⁶.

1.3.2. Reviews of the health impact of water supply, sanitation and hygiene improvements

We know of three reviews of the many health impact evaluations of environmental sanitation that have been performed over the last fifty years^{6,37,38}. Each of these reviews has classified the studies according to whether the interventions improved water quality, water availability, excreta disposal, hygiene or combinations of the four. The most recent one³⁸ updates the findings of the other two and is therefore the one, which will be discussed most thoroughly. Since this review many more studies have been published in which the impact of water supply, sanitation and hygiene is assessed, either alone or in combination with other improvements.

Although the 1991 Esrey *et al* review³⁸ considers the potential health impact of water supply, sanitation and hygiene on trachoma, schistosomiasis, hookworm, dracunculiasis, ascariasis and diarrhoea, it are only the latter 3 diseases which improved water quality for drinking might be expected to prevent. The others are therefore not considered here. Table 2, reproduced from Esrey *et al*,³⁸ shows the median reduction in morbidity and mortality for each disease taking all of the studies combined. It appears from this table that dracunculiasis and schistosomiasis are particularly amenable to water and sanitation interventions. It also seems that mortality is more reduced than morbidity but this may also be due to the difficulties in measuring the latter.

Table 2. Expected reduction in morbidity and mortality from improved water and sanitation for selected diseases

	n	All studies Median reduction (%)	n	Rigorous studies Median reduction (%)
Ascariasis	11	28 (0-83)	4	29 (15-83)
Diarrhoea				
Morbidity	49	22 (0-100)	19	26 (0-68)
Mortality	3	65 (43-79)	-	-
Dracunculiasis	7	76 (37-98)	2	78 (75-81)
Hookworm	9	4 (0-100)	1	4
Schistosomiasis	4	73 (59-87)	3	77 (59-87)
Trachoma	13	50 (0-91)	7	27 (0-79)
Child mortality	9	60 (0-82)	6	55 (20-82)

Source: Esrey *et al*, 1991³⁸

1.3.3. The health impact of combined water supply and excreta disposal improvements

In four well-conducted studies of the review, the prevalence of ascariasis was reduced among those with water supplies and latrines, the greatest reductions being observed in those settings where household water supplies were provided rather than community standpipes. There was a greater reduction in the intensity of infection (as measured by egg counts) than in the prevalence.

For diarrhoea, studies of combined water supply and sanitation improvements show a 20% median reduction in morbidity with the better studies having a 30% median reduction (table 3). In the only study that examines the impact on mortality, an 82% reduction was observed in those with toilets and water compared with those without such facilities, particularly if the child was not breast-fed.

Table 3. Expected reduction in diarrhoeal disease morbidity from improvements in one or more components of water and sanitation.

	n	All studies reduction (%)	n	Rigorous studies reduction (%)
Water & sanitation	7 ^a / 11 ^b	20	2 ^a / 3 ^b	30
Sanitation	11 / 30	22	5 / 18	36
Water quality & quantity	22 / 43	16	2 / 14	17
Water quality	7 / 16	17	4 / 7	15
Water quantity	7 / 15	27	5 / 10	20
Hygiene	6 / 6	33	6 / 6	33

^a The number of studies for which morbidity reduction calculation could be made.

^b The total number of studies that related the type of facility to diarrhoeal morbidity, nutrition and mortality.

Source: Esrey *et al*, 1991³⁸

A recent follow-up cross-sectional survey of a water supply, sanitation and hygiene education intervention in Bangladesh^{39,40}, of which the results were not included in the review, reported about 50% less diarrhoea prevalence in the intervention areas compared to the prevalence of the control areas. See table 4.

Esrey combined data collected in the late 1980's from 8 countries on 3 continents and analyzed them to test whether incremental health effects regarding diarrhoea resulted from incremental improvements in water and sanitation. Optimal (i.e., on the premises) and intermediate (improved public water) water supplies were compared with unimproved water conditions. Optimal (flush toilets or water-seal latrines) and intermediate (latrines) sanitation levels were compared with unimproved sanitation. Results were published in 1996⁴¹. Incremental improvements in sanitation were associated with less diarrhoea with each of the three levels of water supplies and the effect was greater among urban dwellers than among rural dwellers. Benefits from improved water were less pronounced than those for sanitation. They occurred only when sanitation was improved and only when optimal water ('on the premises') was present and not with the intermediate water supplies (not 'on the premises').

VanDerslice had a comparable result in a study in the Philippines⁴². Improving drinking water quality had no effect in neighbourhoods with very poor environmental sanitation. The positive impact of improved water quality was greatest for families living under good sanitary conditions. See table 4.

1.3.4. The health impact of combined water quantity and/or water quality improvements

In many of the studies published, it is difficult to determine whether the water supply improved quantity, quality or both and hence the review grouped them together. Two studies found that water supplies alone, reduced ascariasis prevalence by 30% and 37% respectively. However, for diarrhoea morbidity, only modest reductions (16-17%) were observed (table 3). In the nine rigorous studies which looked at mortality, a positive impact was observed only in certain age groups. The studies reporting positive impacts tended to be the ones where the water supply was piped into the homes as opposed to protected wells, tubewells and standpipes. A recent study from China⁴³ (table 4), found that deep well tap water in the house or yard (average total coliform count 0.23/100cc) was associated with a lower incidence of diarrhoea (38%), hepatitis (73%) and cholera (88%) but not *Shigella*, compared with those using surface water at 10 to 40 meters from the home (average total coliform count 77/100cc).

1.3.5. Studies evaluating the impact of water quality alone

Of the 16 studies that are mentioned in the review, which examined the health impacts of pure versus contaminated water supplies, 10 reported positive effects and the median reduction in diarrhoea morbidity was 17%. Among the 7 more rigorous studies, the median reduction was 15%.

Table 4. Recent studies examining the health impact of water quality on diarrhoea

Country	Type of improvement	Comparison	Observed impact	Ref.
Bangladesh	Sanitation & water quantity & quality	Hand pumps, latrines, hygiene education vs control areas	About 50% reduction in prevalence of diarrhoea	40
	Quality only	Exclusive wet season use of hand pump water	Not significant	39
Multi-country study	Water quality & quantity & sanitation	Incremental improvements	Water only effect with good sanitation and optimal water. Sanitation results in less diarrhoea.	41
China	Water quality & quantity	Deep well tap water in yard vs surface water	Reduction of 38% in diarrhoea incidence	43
Philippines	Water quality & sanitation	Latrine/toilet vs nothing, Level of FC contamination	Only effect of water under good sanitary conditions. Sanitation results in 40% reduction	42
Ghana	Water quality	Borehole and wells vs holes dug in stream beds	Nil on mortality Insignificant association with diarrhoea in dry season	52
Egypt	Water quality	Tap water versus well water for drinking	Nil	47
Malaysia	Water quality	Absence vs presence of FC in water source	Insignificant 23% reduction in diarrhoea	28
		Absence vs presence of FC in drinking water	Insignificant 31% reduction in diarrhoea	28
Nicaragua	Water quality	Piped water vs protected wells vs unprotected wells	Nil	33
Nigeria	Water quality	Borehole vs traditional source	Nil	48-51
Sri Lanka	Water quality	Faecal coliform counts	29% reduction in diarrhoea per ten-fold drop in FC contamination	26
Indonesia	Water quality & sanitation	Cross-sectional study of 11 million people, safe vs unsafe water	50% reduction in diarrhoea in case there is an improvement of 100%	45
	Water quality alone	Idem	43% reduction in diarrhoea in case there is an improvement of 100%	
Saudi Arabia	Water quality	Chlorination stored drinking water, FC counts	48% reduction in diarrhoea incidence	44

There are several studies, published since the review, in which it has been possible to separate out the effect of water quality (table 4). In one of them, carried out in Sri Lanka,²⁶ there was a 29% reduction in diarrhoea associated with a ten-fold drop in faecal contamination. A study in Saudi Arabia⁴⁴ found a 48% reduction in diarrhoea due to the use of chlorinated water. A cross-sectional study in a population of 11 million in Indonesia⁴⁵ used an alternative approach to measure the effect of water and sanitation (a production function) and found highly significant results for the effect of water quality and to a lesser extent for sanitation. In this case safe water included treated surface water, household treatment systems or untreated but uncontaminated water such as piped systems, shallow wells, deep wells, spring captations and rainwater. Rivers, streams and ponds were considered as unsafe water. However the authors did not control for distance to the water source.

Recently a controlled field trial has been performed under the Masai and results were published in the *Lancet*. In this study the effect of solar disinfection of drinking water from a contaminated source on the incidence of diarrhoea was measured⁴⁶. The 'solar' group received a plastic water bottle and was instructed to fill it and place it on the roof in full sunlight and the control group was instructed to place the bottle with drinking water indoors in the shade. The children of the "solar" group experienced a reduction of 34% in diarrhoea incidence compared to the control group.

In contrast, other recent studies in Egypt,⁴⁷ Nicaragua,³³ Nigeria^{48,49,50,51}, Ghana⁵² Malaysia²⁸ were unable to detect any effect of water quality although in the case of the latter, the small sample size may have prevented detection of a significant effect.

1.3.6. Studies evaluating the impact of moderate water quality improvements

The vast majority of evaluated water supply interventions, which specifically address the issue of water quality, has taken water supplies with faecal coliform (FC) counts of, or close to zero, as their reference point, as have the review articles. The median health impact of even such significant reductions in levels of contamination is small compared with those reported for sanitation and water quantity improvements. Clearly one would expect the impact of moderate reductions to be even lower^a.

Nine studies were identified which enable an empirical assessment of this issue. In seven of the nine studies a dose response between the diarrhoeal incidence and the level of contamination could be found. One of these studies from the Philippines⁵³ found little difference between the illness rates of children drinking good quality source water (<1 *E. coli* per 100ml) and those drinking moderately contaminated water (2-100 *E. coli* per 100ml). But children drinking water with over 1,000 *E. coli* per 100ml had significantly higher rates of diarrhoeal disease than those drinking less contaminated water.

Trivedi *et al* in India⁵⁴ studied the effect of 4 different levels of chlorination of highly polluted open shallow wells. Seventy four percent of these wells had 'MPN counts' over

^a Moderate reduction as used here means from thousands down to around one hundred faecal coliforms per 100cc of water.

1,800 per 100ml (table 5). The results demonstrate a clear dose response between the level of contamination and the incidence rate of diarrhoea. One must realize that chlorination of water also means that hand washing will be more effective since the chlorinated water presumably not only removes faecal material but kills or debilitates pathogens.

Table 5. Influence of residual chlorine on water quality and on incidence rates of diarrhoeal diseases

		Control	I	II	III	IV
Residual chlorine		0	0.5	0.4	0.3	0.2
Average MPN count*	Before	820	953	1089	1100	880
	After	727	17	41	49	82
Diarrhoea incidence rate	Before	19.0	20.0	22.2	20.3	10.7
	After	29.5	1.1	1.7	2.1	3.0

*MPN=most probable number of bacteria present per 100 ml

Source: Trivedi *et al*, 1971⁵⁴

In a study in Indonesia⁵⁵ water sources were classified as either 'safe' (uncontaminated piped water, protected springs and treated water), 'less safe' (springs, deep well pumps, shallow well pumps, dug wells and rainwater) and 'unsafe' (rivers, streams, and ponds). In a cross-sectional survey of diarrhoea in 8,600 households, 3.8% of children in the 'safe' group had diarrhoea compared with 4.0% in the 'less safe' and 6.3% in the 'unsafe'.

The authors' case-control study in Nicaragua³³ compared diarrhoea rates in users of piped water sources with users of protected wells and users of unprotected wells. Piped water sources generally had low levels of contamination (<100 FCs per 100ml), while protected wells had high levels of contamination (over 1,000 FCs per 100ml). Unprotected wells (which were mostly small waterholes dug beside rivers and streams) had relatively low mean FC counts during dry periods (179 per 100 ml) but very high levels after rain had fallen (15,000 per 100ml). No difference was detected in diarrhoea incidence between the different water sources.

In a study in Zaire⁵⁶ a trend of increasing diarrhoea incidence with decreasing quality of water provided was found. Incidence was highest in children whose families drew their drinking water from streams or rivers, lower in children whose family was using an unimproved spring, and only half in children from families fetching water from improved springs or hand pump wells. However, the authors did not control for distance to the water source.

VanDerslice presented results of a study in the Philippines⁵⁷ in which diarrhoea became less frequent with increasing quality of drinking water. The protective effect was greater among infants who were not breast-fed. And of course, vice versa, the protective effects

of breast-feeding were greatest when drinking water was more contaminated.

In the UK during an outbreak of waterborne cryptosporidiosis associated with a public water supply, those drinking larger volumes were more likely to become ill²⁰. Another UK study²² had the same results; the more water was drunk from a groundwater supply contaminated with cryptosporidiosis, the higher the risk of cryptosporidiosis. A dose-response relationship was also seen in a study from CDC Atlanta; people who drank more unboiled well water became more ill with cryptosporidiosis⁵⁸.

1.3.7. Studies evaluating the impact of increased water quantity

Of the 15 studies mentioned in the review, which examined the effect of increased amounts of water specifically and independently of water quality, 14 reported positive effects. The median reduction for 7 studies for which this could be calculated, was 27%. Of the 10 rigorous studies a median reduction of 20% was found. Health benefits were greater for children whose families used more water than for those whose families used less. The quantity of water appears to be more important than the quality of water.

Since then very few studies have been performed which measured the amount of water used or the distance of the house to the water supply (a proxy for quantity of water used) and related the outcomes to the incidence of diarrhoea. The above mentioned multi-country study of Esrey⁴¹ found that only 'optimal' water supplies (ie, on the premises) had an impact on diarrhoea and not the 'intermediate' supplies (improved public water) compared to the unimproved traditional water conditions. The difference between the 'optimal' and the 'intermediate' water supply concerns the distance to the water source rather than the water quality. When water supplies are 'on the premises' access to water is high, and the quantity of water used will increase. The public water supplies will be at a certain distance from the house as are the unimproved traditional sources and although the quality of water will be much better, this is clearly not enough to create an impact on diarrhoea incidence.

In the authors' baseline studies of traditional water sources in Nicaragua we found a relationship between water consumption and the distance from the house to the water source⁵⁹. In the case-control study³³ we found an association between the water availability and diarrhoea. Children from homes with water supplies over 500 meters from the house had 34% more diarrhoea than children from houses with a water supply 'on the premises'.

1.3.8. Studies evaluating the impact of sanitation

Esrey's review identified 30 studies on the impact of sanitation on diarrhoea. A reduction of 22% was calculated. For the 18 rigorous studies this was 36% in the five, for which this could be calculated. The other studies reported on nutritional status and mortality. Sanitation was more effective in reducing mortality among nonbreast-fed infants and children of illiterate mothers than among breast-fed infants and literate mothers. Some studies reported that the method of disposal of human faeces determined the magnitude of the impact.

In many parts of the developing world children under the age of 5 years do not use latrines^{27,60}. Children's faeces are often viewed as harmless even though these may be highly contaminated⁶¹. In Bangladesh Zeitlin found that mothers did not realize that faeces cause disease. Half of the mothers had seen their crawling baby touch or eat faeces in the two weeks before⁶². Even when there are latrines these are frequently not used by children^{63,64,65}. Muller⁶⁷ found that faecal pollution of households was more due to the fact that latrines frequently were not used than poor construction or maintenance of latrines.

Since the review of Esrey in 1991 several studies have reported that latrine ownership alone is not associated with a reduction in diarrhoea^{32,33,67}. However, hygiene behaviour around the disposal of human faeces was observed to be significantly related to the incidence of diarrhoea^{27,28,68,69,70,71,72,73}. The authors' study of hygiene practices found that the use of a diaper or underclothes was significantly related to a reduction in diarrhoea incidence, meanwhile the presence of a latrine had no relation⁷⁴. In Nicaragua young children defecate in the yard and do not make use of latrines, simply because they are afraid of the "black" hole. This result also helps to explain Esrey's finding in the review that flush toilets were more effective than pit latrines.

On the other hand, other new studies found a significant relation between diarrhoea and the presence of a latrine^{29,45,56,75}. Furthermore the presence of a latrine may also interact with the magnitude of the health impact of improved water supplies. In the multi-country study⁴¹ improved water supplies had only effect in the presence of good sanitation. 'Optimal' sanitation, ie, flush toilets or water-seal-latrines, was more effective than 'intermediate' sanitation (latrines). Providing human faeces disposal facilities was also more effective in urban settings than in rural communities. In the Philippines⁴² not only private human faeces disposal, but also the sanitary conditions of the community, was seen to interact with the health effect of improved water supplies. The authors of the study concluded that improving drinking water quality would have no effect in neighbourhoods with a very poor environmental sanitation. For interventions to control diseases effectively not only private sanitation, but also public sanitation needs to be improved. As Cairncross argues: "Interventions are needed in both domains (public and private) in order to reach the goal of interruption of the transmission"⁷⁶.

1.3.9. Studies evaluating the impact of hygiene

Esrey's review identified only 6 studies that reported on the impact of hygiene interventions on diarrhoea morbidity. All were rigorous, and the median reduction was 33%. His conclusion is that those interventions which improve human faeces disposal and water quantity, and which are associated with better hygiene practices, produce greater health impacts than improvements in water quality alone. This is particularly so in highly contaminated environments where diarrhoea rates are high. Because the use of more water is not automatic following the installation of water supplies, hygiene education is a necessary part of the intervention.

Since then many hygiene studies have been published, including guidelines and methods of how to investigate hygiene practices^{60,77,78,79}. The water and sanitation studies had

made it clear that only supplying hardware is not sufficient to reduce the incidence of diarrhoea; personal, domestic and community hygiene plays a crucial role in the transmission of diarrhoeal pathogens.

Many of the hygiene studies focussed on handwashing^{70,80,81,82,83,84,85,86,87,88,89,90}. For those, which related hand washing practices with diarrhoeal incidence, a decrease of 30% to 90% was observed. Contaminated hands are highly efficient vehicles for the transmission of diarrhoeal disease. Of the personal hygiene behaviours, hand washing is the most critical determinant of diarrhoea⁹¹. In studies measuring the occurrence of hand washing, low frequencies of this practice are seen; in Malawi 13% of adults washed hands after defecation⁹², in Guatemala 11%⁶⁵. In Nicaragua we saw that 76% of mothers washed their hands before preparing food, but only 26% before eating⁷⁴. People wash their hands in different ways at different times of the day for different purposes; hand washing seems not as much to be linked to health as to social norms⁶⁰. Something alike we already described above, where mothers did not perceive babies' faeces to be important in causing diarrhoea. In order to design cultural appropriate interventions of water supply/sanitation and hygiene the incorporation of anthropological research is indispensable⁶⁰. Mothers will only feel motivated to change practices if they understand the relation of this practice with diarrhoea, as we noted in a study in Nicaragua⁹³.

Other studies, including the authors' hygiene study⁷⁴, not only investigated hand washing but also other hygiene practices in order to design or evaluate hygiene education campaigns^{28,32,40,68,94,95,96,97,98,99,100}. In addition to hand washing and sanitary removal of human faeces, hygiene practices which frequently were found to be related to the occurrence of diarrhoea are food and water hygiene and the cleanliness of kitchen and compound.

Overall levels of hygiene in villages may play an important role as children spend a lot of their time in other households and on the street^{101, 102,103}. Households can share meals or buy water and food from street vendors^{61,104}. In several studies crowding, ie, the distance between houses, was reported as a risk factor for diarrhoea⁶⁴ as well as the number of persons and children per household^{33,105}. Koopman¹⁰⁶ stresses in his article of school hygiene in Colombia that in schools in addition to toilets there are other factors, such as person-to-person contact, that are responsible for the transmission of diarrhoea. He argues that interventions in schools are probably more effective than family-based ones, simply because schools have a central role in the diarrhoea transmission of a village because they disseminate the transmission. If the source of schoolchildren as introducers of disease into the home can be reduced, it seems reasonable that illness in their preschool siblings, who have the highest secondary attack rates to these introductions, can be reduced. Many studies have been published recently in which the effect of faecal contamination on diarrhoea rates in childcare settings is described and where the major route of transmission person-to-person is^{88,107}.

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Chapter 4

The diarrhoeal disease risk factor studies of water supplies, sanitation and hygiene in Villa Carlos Fonseca

Section 4.1

Determinants of drinking water quality in rural Nicaragua

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Summary

One hundred and fifty-three water samples from rural Nicaragua were examined for the presence of faecal coliforms during both wet and dry periods. A linear model was fitted by analysis of covariance with the logarithm of the faecal coliform count as the dependant variable. As expected, traditional water sources were grossly contaminated at all times whereas piped water sources were much cleaner. Hand-dug protected wells had significantly higher levels of faecal contamination than unprotected riverside wells and springs during the dry season. The possible reasons for this unexpected finding are discussed. A close association between rainfall and faecal contamination was demonstrated but the effect of rainfall depended on the type of water source. An association between water quality and the size of the community served by the source was also detected. The finding that stored water was usually more contaminated than fresh water samples is consistent with the results from other studies. Since it is unusual for water quality to be inversely correlated with accessibility, this study site would be suitable for investigating the relative importance of water-borne versus water-washed transmission mechanisms in childhood diarrhoea.

Introduction

It is generally believed that the use of inadequate water supplies relates closely to the high incidence of childhood diarrhoea in most developing countries, in spite of the difficulties that have been encountered in measuring this relationship (Blum & Feachem, 1983; Esrey & Habicht, 1986). Diarrhoea, like all faecal-oral diseases, can be transmitted by both water-borne or water-washed mechanisms (Cairncross & Feachem, 1983). Water-borne transmission occurs when the pathogen is in water that is drunk by a person or animal which may then become infected. Improvements in drinking water quality will reduce water-borne transmission. In water-washed transmission, domestic and personal hygiene plays a key role and therefore disease is prevented by increasing the quantity of water used for hygienic purposes, irrespective of the quality of that water (Cairncross & Feachem, 1983). It is still not known which of these transmission mechanisms is more important for diarrhoea (Feachem *et al.* 1978). Although most work suggests that improvements in water quantity are more likely to reduce the incidence of diarrhoea than improvements in microbiological quality (Esrey & Habicht, 1986; Briscoe, 1978; Esrey *et al.* 1985; Freij *et al.* 1978; Schliessman, 1959), at least one study has shown a greater benefit from water quality improvements, especially in younger children (Hebert, 1984).

The relative importance of these two transmission mechanisms has major implications in the design and construction of rural water supplies. Although water supply projects often increase both the quality and quantity of water used, such interventions are usually very expensive. It is now becoming clear that it is beyond the economic ability of most developing nations to provide sophisticated water supplies to entire populations (Schneider *et al.* 1978; Walsh & Warren, 1979). On the other hand, there are several relatively inexpensive interventions which might independently improve either water quality (e.g. simple chlorinators or filtration systems) or increase water consumption (e.g. hand pumps and well digging). This paper presents the results of a study of the microbiological quality of drinking water sources in rural Nicaragua which will be used in the analysis of a case-control study of the relationship between water quality, water accessibility and childhood diarrhoea.

Materials and methods

The study site was Villa Carlos Fonseca, a rural municipality on the Pacific coastal lowlands with a population of approximately 20 000 spread amongst 35 communities. A population-based survey of the zone was made from a random sample (stratified by community) of 244 (6.7%) of the households on record with the Ministry of Internal Commerce whose consumer census is the most up-to-date population census available. Ministry officials estimate its completeness to be approximately 95%. Each of the houses selected was visited by a trained interviewer who interviewed the female head of household. The water supply for the household was ascertained and inspected. It was thereby possible to classify the different types of water source and to estimate the proportion of the population using each of them.

Sites for monthly water-sampling were chosen at random for each type of water-supply identified in the population-based survey. Additional water samples were also randomly selected at different times to provide sufficient statistical power to test diverse hypotheses. Water samples were collected in sterile glass bottles and transported to the laboratory in a cold box containing freezer packs. In all cases, analysis by the multiple tube method was commenced within 8 hours of collection. The glassware and media were sterilized the day before in an autoclave at 121°C for 15 minutes. Five sets of five tubes were inoculated with 10ml, 1ml, 0.1ml, 0.01ml and 0.001ml of each sample. Samples were incubated first in lauryl tryptose broth (Gibco Laboratories no. 28300) for 24 hours at 37°C in a warm-air incubator. Positive tubes were confirmed by inoculating a further set of tubes containing *E. Coli* medium (Difco Laboratories no. 0314-01-0) and incubating these at 44.5 °C in a water-bath for an additional 24 hours. Most probable number faecal coliform (FC) counts were calculated from the proportion of tubes at each dilution confirmed as positive, that is gas-producing (APHA, 1981).

A linear model was fitted by analysis of covariance with the natural logarithm of the FC counts as the dependent variable. The independent variables considered were; type of water source, recent rainfall, time of sampling (morning or afternoon), presence of a windlass on protected wells, whether the sample was 'fresh' or stored and size of the community from which the sample was taken. The latter was considered large if communities were of greater than 1500 inhabitants. It was thought that this might be an adequate surrogate for population density, especially since the houses in the communities of this size were arranged in street blocks whereas smaller communities consisted of a single main road with occasional side streets. Pairwise comparisons were made using the Tukey-Kramer studentized range test to control for type I experimentwise error (Einot & Gabriel, 1975).

Results

Trained field-workers were successful in interviewing females heads of household at 240 (98%) of the homes selected. Water supplies were classified into five main types: domiciliary connections, public standpipes, protected wells, unprotected wells and springs, and rivers or streams. The domiciliary connections in one area functioned for less than 4 hours per day, but the rest provided water virtually all day and were quite reliable. All public piped water came from boreholes, there being three different boreholes providing water to standpipes and another two different boreholes supplying the networks of domiciliary connections. The protected wells were hand-dug, generally to a depth of about 4 metres, and were surrounded by a precast concrete headwall. As a rule they were partially lined by stone which was sometimes joined to the headwall by mortar. Water was drawn in a bucket on a rope supported by a crossbar and pulley. Many were roofed and some had a windlass, but none incorporated a drainage apron. They were usually privately owned and sited in the yards of peoples homes. Springs and unprotected wells were shallow holes in the ground usually adjacent to rivers in which water accumulated either by filtering up from below or by seepage from above (or both). They were often carved out

from sandstone. As the springs and unprotected wells formed an indistinguishable continuum they will both be referred to as unprotected wells. None of the water supplies were treated.

The proportion of houses with each type of water source is shown in Table 1 together with the number of water samples taken from each. The number of samples taken during the wet period is low due to the drought in 1986 which greatly reduced the length of the wet season.

Table 1. Population and water sample distribution by water source

Water source	Population served (%)	No. of sources tested	No. of samples taken		
			Wet period	Dry period	Total
Rivers and streams	2.5	5	3	16	19
Unprotected wells and springs	26.3	13	6	25	31
Protected bucket wells	52.5	15	5	37	42
Protected wells with pumps	2.0	7	0	11	11
Public standpipes	1.7	3	3	21	24
House connections	15.0	7	3	23	26
Total	100	50	20	133	153

The complete model fitted is shown in Table 2, together with the significance level for each variable. Only those interactions found to be statistically significant are shown. In fitting the model, each monthly measurement of a single source is considered as an independent sample as it was noted that there was almost as much water quality variation for

Table 2. Parameters included in the water quality model

Variable name (and type)	Range of values
Main effects	
Type of water source *** (categorical)	1=rivers/stream 2=unprotected wells 3=protected bucket wells 4=protected wells with pumps 5=public standpipes 6=house connections
Rainfall period ** (dummy)	0=dry period (July-December) 1=wet period (mid-May-June)
Community size * (dummy)	0=small (≤ 1500 inhabitants) 1=large (> 1500 inhabitants)
Storage *** (dummy)	0=fresh sample 1=sample from storage vessel
Interactions	
Type of water source by rainfall **	

* $P < 0.05$ ** $P < 0.01$ *** $P < 0.0001$

repeated samples from the same site as there was for different samples from different sites.

Geometric mean FC counts of each water source for the wet and dry periods are shown in Table 3. All mean values quoted are 'least squares means' which adjust the estimates to allow for the unbalanced design. There were not enough samples taken during the wet period to permit pairwise comparisons but the quality of piped water is obviously much better than that of traditional sources. It would be interesting to obtain sufficient samples during this period to test whether protected wells are less contaminated than the unprotected sources. For the dry period, the distribution of FC counts by water source is plotted in Fig. 1a. Pairwise comparisons were made using the Tukey-Kramer studentized range test (Fig. 1b).

Table 3. Geometric mean faecal coliform counts by water source for each weather period

Water source*	Weather period	
	Wet period	Dry period
Rivers and streams	14 700	11 100
Unprotected well and springs	15 250	179
Protected bucked wells	4 300	1 410
Protected wells with pumps	No samples taken	22
Public standpipes	19	11
House connections	2	0

* Does not include stored water samples

The nature of the water source/rainfall interaction can be seen in Table 3. While the quality of water drawn from springs and unprotected wells improves strikingly in the dry period, the quality of other sources did not change greatly. Unprotected wells and springs seem to be more contaminated than protected wells during the wet period, but they are significantly less contaminated during the dry period.

Table 4 shows for each type of water source how the quality depends on the size of the community from which the water was sampled. The quality of piped water sources does not depend on the community size but it appears that the quality of traditional water sources does. In fact for piped water, quality seemed to improve in the larger communities but this difference is unlikely to be significant.

Rivers and streams

Unprotected wells and springs

Protected bucket wells

Protected wells with pumps

Public standpipes

Domiciliary connections

Fig. 1(a). Histograms of geometric mean faecal coliform counts by water source for the dry period.

Table 4. Geometric mean faecal coliform counts by water source and community size

Water source*	Community size †	
	Large	Small
Rivers and streams	27 800	5 760
Unprotected wells and springs	767	83
Protected bucket wells	1 450	977
Protected wells with pumps	16	39
Public standpipes	No samples taken	
House connections	0	5

† There were 3 communities considered to be large and 16 communities classified as small.

* Does not include wet period or stored water samples.

As indicated in the Table 2, water stored in homes is significantly more contaminated than water drawn directly from the source. The geometric mean FC count of stored water from domiciliary connections was 94 compared with 0 for the unstored samples. There were not enough samples to determine how domestic storage affects water drawn from other sources.

Of the 42 samples taken from protected bucket wells, 6 were taken from wells incorporating a windlass. It was hypothesized that the presence of a windlass on a protected well would reduce the contamination since the rope does not drag on the ground. In fact, the

Fig. 1(b) Geometric mean faecal coliform counts with 95% confidence limits by water source for the dry period. N.B. Does not include wet period or stored water samples.

(least squares) geometric mean FC count of those wells with a windlass was 1420 compared with 1100 for those without ($P=0.77$), though caution should be exercised in interpreting this result owing to the small number of samples from wells with a windlass.

Discussion

In many ways this analysis confirms the results obtained from several other studies in that the quality of water was found to depend greatly on the type of water source from which it is drawn, the weather prior to the time of sampling, and whether it was taken directly from the source or from a storage vessel in the home (Freij *et al.* 1978; Schneider *et al.* 1978; Shiffman *et al.* 1978; Young & Briscoe, 1987; Muhammed & Morrison, 1975; Torun, 1982; Barrell & Rowland, 1979). It does not pretend to take into account all the variables that have been considered in other work (e.g. soil type, well diameter, depth, distance to the nearest latrine, etc.) and there are other variables which might affect the water quality of domestic wells which have not generally been considered in this type of study (e.g. literacy, presence of domestic animals, etc.).

As in other studies, there is a very high level of contamination in the traditional water sources. The unexpected finding was that protected domestic wells were significantly more contaminated than unprotected riverside wells and springs during the dry period. Most studies of rural water quality have found that protected sources are generally less polluted than unprotected sources. Tomkins *et al.* (1978) and Wright (1982) both found that protected wells were less contaminated than unprotected wells during the dry season. Isely (1978) and Lehmusluoto (1987) also both found protected springs to be less contaminated than unprotected springs though in the latter study the difference was not statistically significant. On the other hand in Nigeria (Blum *et al.* 1987) found significantly lower faecal streptococci counts in ponds and unprotected springs than in traditional wells during the period of lower contamination, but it was not clear how well protected their 'traditional wells' were.

There are two possible explanations for the observed difference in water quality between the protected and the unprotected sources. One is that the protected wells are exposed to greater faecal contamination in spite of their protection. The other is that a structural difference tends to make the unprotected water sources less polluted during the dry period.

The first hypothesis is supported by the fact that protected wells in this part of Nicaragua are almost all privately owned and located close to houses where children and domestic animals defecate openly. Also, 72% of these wells are in homes with latrines although most of them are situated at least 10 metres from the well (Sandiford *et al.* unpublished results). In contrast, the unprotected wells are usually dug beside rivers and streams 50-100 metres from the nearest houses.

It would seem unlikely that a structural difference could explain why unprotected wells have lower FC counts during dry weather than protected wells. Protected wells all have

parapets at least one metre high, they usually incorporate a crossbar and pulley, and often have a roof, a cover, and/or a windlass, while unprotected wells are much shallower and do not have parapets. One important feature of the unprotected well though, is the small volume of water which it holds (usually only 20-40 litres). As each generally serves several families, the high demand for water creates a rapid turnover which would readily eliminate externally introduced contaminants. It has been observed that some families empty these wells and allow them to refill each time they collect water (Pauw *et al.* in preparation). The protected wells on the other hand, contain a much greater volume of water which is emptied by their owners only once or twice a year.

Though more research is needed to determine the relative importance of these two explanations the quality of water from protected wells does appear to be more variable than that from unprotected wells (Fig. 1a) suggesting that certain factors in the domestic environment may give rise to contamination. Not all protected wells had higher counts than unprotected wells.

It is notable that the presence of a windlass appeared to have no effect on the water quality of domestic wells. Those with an electric pump to extract the water were significantly less contaminated than those using a bucket and rope, in spite of being virtually identical in other respects. It is possible that much of the contamination of protected bucket wells originates from water spilt around the parapet seeping back into the well. Pumps which pipe water away from the well clearly avoid this problem. The complete absence of drainage aprons in the Nicaraguan wells studied makes them rather susceptible to this type of pollution (Cairncross & Feachem, 1983).

The poor quality of springs and unprotected wells during periods of rainfall is probably due to run-off into the wells. Similar problems have been noted with unprotected springs in other studies (Moore, de la Cruz & Vargas-Mendez, 1965; Barrell & Rowland, 1979). It would be interesting to investigate the impact of spring protection during the rainy periods. A modest drop in the quality of domestic well water was also noted with the rainfall which is consistent with other studies (Voelker & Heukelekian, 1960; Barrell & Rowland, 1979).

Community size was found to be significantly associated with water quality and this was particularly noticeable in the rivers, springs and unprotected wells. An association between water contamination and proximity to towns has previously been reported (Muhammed & Morrison, 1975; Bradley & Emurwon, 1968) but only for rivers and streams. It may be that the more families using a source, the greater the potential for contamination. In fact the mean number of houses using unprotected wells and springs in large communities is 4.2 compared with 2.9 in smaller communities (Sandiford & Gorter, unpublished results). Community size did not seem to affect the quality of protected well water where an average of 2.2 families are served by each well in both small and large communities.

This study has shown that water quality in protected wells is not always better than that in unprotected wells, though the reasons are not entirely clear. More research is needed to determine the most cost-effective means of protecting hand-dug wells. If cheap but effective structural modifications to traditional water sources can be found, these may prove to be appropriate interventions for the prevention of water-borne illnesses.

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Section 4.2

Determinants of domestic water use in rural Nicaragua

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Summary

In order to investigate the factors affecting domestic water use in rural areas of developing countries, an analysis was performed of water consumption estimates from 1029 different households in Nicaragua collected between May 1986 and December 1988. Eight of the 22 variables hypothesised to be related to per capita domestic water consumption, were included in the final multiple regression model. These were; household size, site of clothes washing, the type of water source, mother's and father's levels of schooling, distance to the water source, wealth, and ownership of cattle. According to this model, a decrease in the distance to the water source from 1000 to 10 metres is associated with an increase in per capita water consumption of 20%. Similarly, families where the mother has 6 years of schooling use 17% more water than families where the mother has had no formal education. The same difference in the father's schooling is associated with 12% greater per capita water consumption. A better understanding of the factors affecting domestic water use is needed to improve the design of interventions aimed at reducing the transmission of water-washed disease in developing countries.

Introduction

It is now become apparent that the quantity of water used for the purposes of domestic and personal hygiene is an important factor in the control of diarrhoea (and possibly other faecal-oral diseases) (Esrey & Habicht 1986; Esrey *et al.* 1985; Victora *et al.* 1988; Sandiford 1989). Increasing domestic water use in many settings is believed to be at least as effective in preventing diarrhoea morbidity and mortality in children as improving the microbiological quality of drinking water (Cairncross 1987). In fact, some of the spectacular failures of water supply interventions to improve child health and survival can be attributed to the absence of any significant increase in domestic water consumption by the intended beneficiaries (Kawata 1978; Schliessman 1959).

There is therefore clearly a need to develop water supply and health promotion interventions which raise per capita domestic water consumption and/or increase the proportion of domestic water used for purposes of domestic and personal hygiene. A review of the published literature revealed a poverty of information on the factors related to domestic water use in rural areas of developing countries.

Given the well-recognised public health importance of childhood diarrhoea in developing countries, such a gap in our knowledge is of some significance. This paper presents an investigation of the variables related to water consumption obtained from a large case-control study of diarrhoea performed in rural Nicaragua from May 1986 until December 1988. It is not intended to be a definitive study of all the possible factors which combine to determine behavioural patterns of water use. Rather, it is an exploratory analysis of certain correlates of rural domestic water use, with a view to contributing to the design of health promotion programmes which maximize the quantity of water used for domestic and personal hygiene, with or without structural improvements in rural water supplies.

Material and methods

The study was carried out in Villa Carlos Fonseca, a rural municipality on the Pacific coastal plains of Nicaragua with a population of approximately 30 000. Children under the age of 5 years who presented with diarrhoea to health facilities in the study zone were matched by age and clinic to children presenting with non-diarrhoeal illnesses (mainly acute lower respiratory tract infections). A total of 1228 episodes of diarrhoea and 1228 control illnesses were recruited to the study. Trained interviewers collected data on a variety of factors from female heads of household at their homes. These included reported daily water consumption, the types of water source, distance from the house to the water source(s), the ownership of cattle and presence of domestic animals, the parents' occupations and levels of education, indicators of socio-economic status, and household size including the proportion of inhabitants under the age of 5.

Water consumption estimates were not collected from houses with piped water as the

precision of the data was likely to be low. Therefore water consumption figures were available for only 1962 of the 2456 interviews. The selection procedure used for the case-control study was such that children could be recruited on more than one occasion so some homes were visited more than once. The 1962 figures for water consumption were thus obtained from a total of 1455 separate interviews, of which 1029 were initial visits and 426 were repeat visits (after an interval of at least 3 months). The repeatability of the mothers' water consumption estimates was assessed by comparing the rates given at the initial visit with those obtained in the repeat interview. Only the first home visits were used in the analysis of the factors relating to domestic water consumption.

Per capita daily domestic water consumption (PCWC) was obtained by dividing total daily water consumption by the number of household inhabitants. The total water consumption was calculated by the computer programme for data entry which multiplied the volume of each water container by the number of times it was filled in a day. The fact that there is little variety in the bucket size used for water collection in Villa Carlos Fonseca made it a simple matter for field workers to estimate the volumes. The result was then tested for association with 22 factors which could potentially influence it, using a linear regression model.

Following the recommendations of MacClure and Willett (1987), the measurement of repeatability for the continuous and ordinal scale variables was evaluated by the intra-class (i.e. within household) correlation coefficient. For indicator variables, repeatability was measured using the kappa score which takes into account the degree of concordance to be expected by chance alone (Fleiss 1981). Negative kappa scores indicate less concordance than that which would be expected by chance. Positive kappa scores suggest better concordance than that expected by chance with kappa scores of 1 representing perfect agreement between the repeated measurements. For dichotomous variables, it is generally accepted that values below 0.40 imply poor repeatability, 0.40 to 0.75 good repeatability, and values above 0.75 indicate excellent repeatability (Fleiss 1981). It is important to bear in mind that kappa scores for variables with more than two categories tend to be lower than those for dichotomies. In the statistical analysis, the natural logarithm of daily per capita domestic water consumption $\log(\text{PCWC})$ was used as the dependent variable in fitting a linear model by analysis of covariance. The transformation was performed in order to make the variance of $\log(\text{PCWC})$ approximately the same for each value of the independent variables and to normalise the distribution of the residuals. The final model was arrived at by stepwise inclusion of the variable which at each stage gave rise to the greatest statistically significant ($P < 0.05$) improvement in the goodness of fit. At the same time, any variable whose exclusion did not significantly reduce the goodness of fit was removed from the model at each stage. Interactions between the hypothesized factors were also assessed for statistical significance.

Table 1. Repeatability of measurement of the parameters studied.

Variable	
Continuous variables	
Total daily water consumption	Intraclass Correlation Coefficient 0.57
Household size	0.64
Per capita water consumption	0.45
Log (per capita water consumption)	0.44
Mother's level of schooling	0.89
Father's level of schooling	0.79
Distance to the water source	0.65
Log (distance to water source)	0.73
No. houses sharing water source	0.71
No. of under 5-year-olds	0.51
Frequency of drawing water*	
children	0.45
women	0.41
men	0.44
Indicator variables	
	Kappa score
Type of water source	0.84
Site of clothes washing	0.58
Site of bathing	0.59
Presence of a latrine	0.75
Literacy of mother	0.77
Literacy of father	0.67
Mother's occupation †	0.56
Father's occupation †	0.68
Type of flooring in house	0.74
Electric power	0.76
Domestic animals owned	
pig	0.47
horse	0.57
poultry	0.32
cattle	0.66
Ownership of land (yes/no)	0.60
Drinking water protection	0.31

* Ordinal variables with three levels corresponding to 'usually', 'sometimes' and 'never'.

† These variables each have four levels of classification. All others are dichotomous.

Results

Table 1 lists the 22 factors hypothesized to be related to PCWC and presents the repeatability estimates for each.

The variables included in the final regression model are shown in Table 2. Although it was found that PCWC is greater when men contribute to water collection, this variable was not included in the final regression model because it was felt that the involvement

of men in water collection may be a consequence of high rates of PCWC rather than a cause. None of the interactions tested were found to be statistically significant. In particular, the likelihood of the child suffering from diarrhoea was found to be unrelated to per capita domestic water consumption whether as a main effect or as an interaction term.

Table 2. Variables included in the final regression model of water consumption

Variable	Coefficient	Std error	t-Value
Household size	-0.0761	0.0059	12.82***
Site of clothes washing	-0.2461	0.0517	4.77***
Type of water source	-0.1731	0.0472	3.66***
Mother's level of schooling (years)	0.0267	0.0083	3.22**
Father's level of schooling (years)	0.0190	0.0073	2.67**
Log (distance to the water source)	-0.0401	0.0156	2.56*
Type of flooring in the house	-0.1147	0.0503	2.28*
Ownership of cattle	0.0785	0.0386	2.04*
Constant term	4.0186	0.0842	47.75***

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.0005$

As the dependent variable in the regression model was the natural logarithm of PCWC, the coefficients obtained represent relative rather than absolute differences. The effect of each variable is therefore best expressed in terms of the associated percentage increase or decrease in PCWC. These differences are summarized in Table 3 which shows mean values and the percentage change in PCWC for each level of the variables included in the final model. The effect of water availability (as measured by the distance from the home to the main water supply) on PCWC is portrayed in Figure 1. It was found that a logarithmic transformation of the distance from the home to the water source improved the fit of this variable in the regression model. The crude PCWC rates (and their 95% confidence limits) were calculated by taking the geometric mean PCWC within log-distance intervals of equal size.

Discussion

The repeatability of the mother's daily per capita domestic water consumption estimates was not very high, perhaps owing to the fact that PCWC is calculated as the ratio of two other variables (total daily household water consumption and the number of household inhabitants), each of which is subject to measurement error. As no objective measure of PCWC was obtained, it is uncertain to what extent these estimates reflect actual rates of water consumption. Cairncross and Cliff (1987) found that observed domestic water consumption was quite similar to reported water consumption in a study performed in Mozambique, though the estimates were obtained from different samples of the population. No published research has been identified which directly compares observed with reported rates of water consumption. It would be valuable to know how accurately

women estimate their household water consumption. This would permit comparisons of the relative efficiency of observation versus interview as data collection methods for studies of water use.

Table 3. Levels and changes in PCWC associated with the indicator variables included in the regression model.

Variable	Mean PCWC (l/person/day)	Crude % change	Adjusted % change
Site of clothes washing			
in the home	32.8		
at the river	20.7	-36.9	-21.8
Ownership of cattle			
not owned	24.0		
owned	23.1	-3.8	8.2
Flooring of house			
tile or concrete	29.7		
clay	22.4	-24.6	-10.8
Type of water source			
protected well	27.7		
river/spring/unprotected well	18.2	-34.3	-15.9
Mother's level of schooling*			
nil	19.9		
3 years	23.1	16.1	8.3
6 years	27.5	38.2	17.4
9 years	37.2	86.9	27.2
Father's level of schooling*			
nil	20.5		
3 years	23.4	14.1	5.9
6 years	28.0	36.6	12.7
9 years	23.9	16.6	18.7
Household size*			
4 persons	32.9		
8 persons	23.3	-29.2	26.2
12 persons	18.8	-42.9	45.6
16 persons	23.7	-28.0	59.9

* Crude and adjusted percentage change is in relation to the minimum level shown in the table.

Of the total variance explained by the regression model (28.7%), a large proportion (12.3%) was attributable to just one variable, namely household size. The inverse correlation between PCWC and household size can be explained by the economies of scale in certain activities requiring water, such as cooking and cleaning the house. Only a minority of water uses (e.g. drinking and bathing) can be expected to increase in direct proportion to the number of people living in the house. Household size has consistently been found to be inversely related to PCWC in previous studies (Darr *et al.* 1975; Feachem *et al.* 1978; White *et al.* 1972; Wong 1987).

Figure 1. The relationship between water consumption and the distance from the house to the water supply. —, Crude regression line; ----, adjusted regression line. Bars represent mean and upper and lower 95% CI.

The importance of the site of clothes washing is mostly a consequence of the way PCWC was measured. Water consumption estimates by female heads of household pertain only to water carried home. They do not include water which is used for washing clothes at the source. Furthermore, those families which wash clothes at the river generally bathe there too. Though the site of bathing was also included in early regression models, it became statistically insignificant when the site of clothes washing was introduced. Obviously, the high level of collinearity existing between the site of clothes washing and the site of bathing makes it difficult to separate the independent effects of one from another. The 21.8% lower PCWC in households washing clothes at the riverside compared with those who perform their laundry at home is thus an indication of water used for bathing as well as for clothes washing.

A statistically significant relationship was identified between water availability and

PCWC. This is consistent with results from research in Thailand (Frankel & Shouvanavirakul 1973), but not all investigations have demonstrated such a correlation. In studies performed in Lesotho (Feachem *et al.* 1978) and in East Africa (White *et al.* 1972), per capita water use did not decrease significantly for un piped rural areas until the source was at least 1 km from the home. The constraints of linear regression modelling prevent one from defining the shape of the adjusted distance/PCWC curve, but it is interesting that the crude relationship shows some similarity to the model postulated by Cairncross (1987) on the basis of studies in Africa. According to this model, PCWC increases sharply when water is supplied to the home or yard but flattens out for return journey times from 10 to 30 minutes and then decreases gradually for distances greater than 1 km. The crude rates plotted in Figure 1 offer some support for this model. For water sources up to 18 m from the house, PCWC varies little. From 18 to 180 m PCWC drops from 27.9 to 19.1 l per person d⁻¹. There is then virtually no change in PCWC for distances up to 560 m. PCWC falls again from 18.7 to 13.2 l per person d⁻¹ between 560 and 1800 m.

It should be recognised, however, that these are crude rates which do not allow for factors such as the change in site of clothes washing which could partly explain the observed falls in PCWC. It is for this reason that the slope of the unadjusted regression line is much steeper than the adjusted regression line. It seems that as distance from the house to the water source increases, people change their patterns of water use; more families bathe and wash clothes at the river rather than carry the water to their homes. Nevertheless, there remains a small but statistically significant, independent effect of water availability on PCWC. This was also found by Frankel and Shouvanavirakul (1973) who noted that when public standpipes were far from villagers' houses (they do not state how far), washing and bathing occurred at the site of water collection, but even allowing for this change in the pattern of water use, PCWC was still higher in the villages with closer water sources.

A close relationship was found between water consumption and the type of household flooring (clay versus concrete or tile), a variable found to be a good indicator of wealth in this setting (Sandiford *et al.* 1989). The correlation between wealth and PCWC persisted even after controlling for water availability, education levels, the ownership of cattle, household size and the site of clothes washing (although the relationship was weaker). Other studies have also observed associations between water consumption and socio-economic indicators (Darr *et al.* 1975; White *et al.* 1972; Wong 1987). There are several reasons why poor people might consume less water. On the one hand they may have fewer tools or equipment associated with water use, smaller gardens, or fewer containers and less time to draw water. On the other hand, there may be cultural factors such as differences in hygiene practice between the wealthy and the poor. The relative importance of cultural factors in domestic water use is supported by the associations which have also been noted with parental schooling (Darr *et al.* 1975; Wong 1987) and race (Darr *et al.* 1975) and by White and colleagues' finding that PCWC 'seems to be more sensitive to gross differences in material wealth from one area or culture to another than within such groups'.

Parental schooling emerged as a particularly strong determinant of PCWC in this analysis. The mother's and the father's levels of education each independently predicted PCWC. Other studies have either found no relationship with schooling (White *et al.* 1972) or have not distinguished between male and female levels of education (Darr *et al.* 1975; Wong 1987). In Nicaragua, the father's level of schooling is probably a reasonable proxy for family income while the mother's level of schooling may indicate more cultural family characteristics such as hygiene practice. More work is needed to identify the precise mechanism by which education affects PCWC.

PCWC was significantly higher in households drawing water from protected wells than from unprotected shallow wells, springs or rivers. One reason may have been the limited capacity and flow of water from unprotected wells and springs. It is customary to 'clean' these wells by emptying them with a small basin before and allowing them to refill before drawing water (Sandiford *et al.* 1989). This takes about 30 minutes in the dry season and thus adds considerable time to daily water collection. Another possible reason for the lower PCWC associated with these sources is that the riverbeds where they are found are often at the bottom of steep paths. The importance of terrain has been mentioned by White *et al.* (1972).

No significant variation in water consumption between the dry and wet seasons was detected in this study. This is consistent with results from East Africa (White *et al.* 1972), but in Thailand, rainwater collection during the wet season reduced the demand from piped water sources. In contrast, rainwater use is not common in this area of Nicaragua.

Families with cattle had higher rates of PCWC than those without, but only after controlling for the other variables in the model. The 8.2% difference in PCWC is likely to be an underestimate as in some cases cattle were watered from a different source so their consumption was not included as a part of domestic water use.

The multiple regression model developed in this analysis, while a useful first approximation is undoubtedly deficient in several respects. Only a small proportion of the total variance in water consumption estimates was explained by the various factors tested. Although much of the residual variance could be accounted for by measurement error associated with the rather low repeatability of the mother's water consumption estimates, there are also factors which have been found to be significant in other studies which were not tested in this analysis. They include the size of the water container, the number of baths per day, and family income.

One should note that PCWC was found to be unrelated to the case/control status of the child suggesting that water consumption may not be an important risk factor for childhood diarrhoea in rural Nicaragua. However, in another analysis it was found that the distance from the house to the water source (i.e. the availability of water) was significantly associated with diarrhoea (Sandiford, 1989). A likely explanation for this is the low repeatability of water consumption estimates (as measured by the intraclass correlation coefficient), compared with the repeatability of water availability measurements.

This could mean that the distance from the house to the water source is actually a better proxy for the quantity of water used in hygiene-related activities than the per capita domestic water consumption estimate itself, especially since the water used by a family for the practice of hygiene may be only a small proportion of total daily water consumption.

It is clear from this analysis that several factors are important determinants of domestic water consumption. Those most likely to be related to the amount of water used for hygiene practice (and therefore to diarrhoea morbidity) are the mother's and father's level of schooling, the distance from the home to the water source, and the type of water source. Given the strength of the association between water supply and schooling, it may prove more cost-effective, in some settings, to increase domestic water consumption for hygiene (and thereby reduce child diarrhoea morbidity) by educational interventions than by structural improvements in water supplies.

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Section 4.3

Water supply, sanitation and diarrhoeal disease in Nicaragua: Results from a case-control study

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Abstract

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

Introduction

It is well known that acute diarrhoeal disease is one of the most important causes of morbidity and mortality in children under five years of age. Mortality rates of over 20 per 1000 children in their first two years of life have been reported in Latin American countries and average morbidity rates are estimated at two episodes per year¹.

The use of oral rehydration therapy has been promoted to reduce diarrhoea mortality, recognising that other strategies are necessary to reduce diarrhoeal morbidity². In 1982, the Diarrhoeal Diseases Control Programme of the World Health Organization commenced a systematic study of the strategies that might play a role in the control of diarrhoea. One of the seven strategies considered to be viable was the improvement of water supplies and sanitation³.

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

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

Since then, efforts have been made to develop rigorous methodologies to measure the health impact of strategies aimed at reducing diarrhoeal morbidity⁷. The outcome of this has been the application of case-control designs whose superior efficiency in comparison with cohort studies, even for investigating common diseases, allows data of higher quality to be collected⁸. This article presents results from one application of the case-control method to the study of the relationship between acute diarrhoeal disease and environmental risk factors.

Methods

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

A random sample of houses registered with the Ministry of Internal Commerce's consumer census was visited in order to determine the prevalence of the different types of water supply and sanitation. A subsample was then selected of sites representative of each type of water source from which monthly samples were taken to measure microbiological water quality by faecal coliform count. The results from a multivariate analysis of the water quality data have been published elsewhere⁹.

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

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

Specifically excluded from the control group were children diagnosed as having hepatitis, typhoid or parasitosis, or presenting with nausea, stomach pains, breast-milk intolerance or mild diarrhoea. Children with any form of trauma were also excluded from the control group because it is believed that they may be drawn from a different population than those who present with diarrhoea and thus their inclusion would introduce selection bias⁸.

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

Field workers unaware of the subject's diagnosis were sent to the home of each child in order to verify by direct observation the type of water supply and presence or absence of

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

Least-squares linear models were fitted to identify the determinants of bacteriological water quality⁹ and household water consumption¹⁰. The ratio of discordant pairs was used as an estimator of the incidence rate ratio for the different levels of each risk factor. The rate ratio was tested for statistical significance using McNemar's test in the first place and then by conditional logistic regression while controlling for confounding variables. The 95% confidence intervals were estimated by maximum likelihood.

Results

Water Quality

The six main types of water supply identified in the population survey were rivers and streams, unprotected wells, protected wells, wells with mechanical pumps, public stand-pipes and domiciliary connections. Unprotected wells include springs and generally consist of shallow holes dug at the bank of a river or gully. Protected wells are usually at least seven metres deep and are surrounded by a parapet with the water drawn in a bucket on a rope.

The (geometric mean) faecal coliform counts obtained from each type of water source are shown in Figure 1. There was a marked difference in the degree of contamination of piped water compared with water from wells or other traditional sources. It was surprising to discover that during periods of low rainfall, the water quality of the unprotected wells was better than that of protected wells. Water quality was worse during wet periods, especially in the unprotected wells. The results of the water quality analysis have been presented elsewhere⁹.

Relationships between Water Supply and Diarrhoea Morbidity

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

* No samples were taken from wells with pumps during the wet period

Figure 1. Geometric mean faecal coliform counts by type of water source during wet and dry weather (months with >200 mm rain defined as wet)

Figure 2. Monthly rainfall and recruitment of subjects.

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

Water availability was significantly associated with diarrhoea when included in the logistic regression model as a continuous variable, implying that the frequency of diarrhoea increases exponentially with unit increases in the distance from the house to the water source (Figure 3). Thus, in houses with a water sources 500 metres away, children had

* Compared with homes adjacent to their water supply

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

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

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

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

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

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

34% (95% CI 2-56%) more diarrhoea than in houses adjacent to their water supply.

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

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

Discussion

The results presented support the notion that access to water is an important risk factor for diarrhoea. Most studies have not attempted to obtain separate estimates for the impact of water quality and water availability, (indeed the two are often highly correlated making this difficult to achieve in practice), but there are two review papers which divide health impact evaluations of water supply into those where the improvement was predominantly in water quality, and those where the improvement was mainly in water availability. The first of these found that the median percentage reduction in diarrhoea incidence for studies where the improvement was mainly in water availability was 25% compared with 16% for those studies where the improvement was predominantly in water quality⁴. The second paper which reviewed many of the same studies, showed that the highest proportion of studies reporting a positive impact were those where the intervention resulted in increased water availability⁵. Our findings are consistent with these results as it was found that high rates of diarrhoea occur in the houses with water sources more than 500 metres away. At distances under 500 metres however, the effect of water availability is small.

Since these reviews there have been several case-control studies of diarrhoea and environmental sanitation^{11,12,13,14,15}. Two of them^{11,12} assessed the joint impact of improved water supply (mainly water quality) and excreta disposal facilities compared with neither or just one of these interventions. These studies did not report statistically significant effects although they were the earlier case-control studies with rather small sample sizes.

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

The Lesotho case-control study¹⁴ showed an association between diarrhoea morbidity and latrine ownership which was statistically significant in crude analyses but not in the

logistic regression analysis (although the odds ratio remained 0.76). Diarrhoea also showed crude associations with water consumption and with the type of water supply (which may be a proxy for water quality) but these were not analysed by logistic regression.

In a case-control study performed in Sri Lanka, diarrhoea morbidity was significantly related to the type of water source both before and after adjusting for confounders¹⁵. The authors believe that this is an effect more of water quality than of water availability. When disease status was compared with geometric mean faecal coliform counts (adjusting for source and area) there was a small but statistically insignificant difference between cases and controls.

It is difficult to make any general statement about the relative importance of water quality, water availability or sanitation from these studies. Their importance may actually vary from one country to another according to differences in geographical setting, behaviour patterns, transmission routes of the common aetiological organisms, or the nature of the water supplies and excreta disposal facilities. It is also possible that the inconsistencies derive from biases in one or more of the studies.

Our results suggest that the transmission of diarrhoea in Nicaragua is predominantly water-washed rather than water-borne. Where the prevention of diarrhoea is an important consideration in the design of water supply projects, the main focus should be on improving water availability and not water quality. It implies that the practice of boiling drinking water (advice frequently included in health education materials in Nicaragua) may be of little benefit. Taking into account the cost for the family of boiling water and its other disadvantages¹⁶, it may be wise to reconsider the inclusion of this advice in health education programmes. On the other hand, it was not possible in this study to assess whether the lack of an association between water quality (at the source) and diarrhoea was in part due to the practice of boiling water in the home. Recent observational studies performed in Villa Carlos Fonseca however, suggest that drinking water for infants is not usually boiled (unpublished results).

The strong association between maternal schooling and child health has been demonstrated previously in Nicaragua^{17,18} and elsewhere¹⁹. Although the precise mechanism by which child health depends on a mother's level of education is unknown, it is plausible that hygiene practice is important²⁰. This is supported by the correlation found between per capita domestic water consumption and maternal schooling¹⁰. It is possible that as well as using more water, educated mothers also dedicate a greater proportion of the water they collect to hygiene-related activities.

At this stage however, there is only indirect evidence for an association between hygiene practice and maternal schooling. Education is a complex social variable and its relationship with health could have several components. A mother's education is closely associated with socio-economic status, with access to health services, with intrafamilial power relationships, and with her health-seeking behaviour when the child is ill. The lack of a

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

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

The results obtained from this study do not allow comment on the efficacy of other methods for preventing diarrhoea recommended by the World Health Organization, such as the promotion of breast feeding, measles immunization or improvements in weaning practice³. The study does suggest that improvements in water availability and hygiene education can be effective interventions for the prevention of child diarrhoea.

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Section 4.4.

Hygiene behaviour in rural Nicaragua in relation to diarrhoea

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Abstract

Background. Childhood diarrhoea is a leading cause of morbidity and mortality in Nicaragua. Amongst the risk factors for its transmission are 'poor' hygiene practices. We investigated the effect of a large number of hygiene practices on diarrhoeal disease in children aged <2 years and validated the technique of direct observation of hygiene behaviour.

Methods. A prospective follow-up study was carried out in a rural zone of Nicaragua. From the database of a previously conducted case-control study on water and sanitation 172 families were recruited, half of which had experienced a higher than expected rate of diarrhoea in their children and the other half a lower rate. Hygiene behaviour was observed over two mornings and diarrhoea incidence was recorded with a calendar, filled out by the mother, and collected every week for 5 months.

Results. Of 46 'good' practices studied, 39 were associated with a lower risk of diarrhoea, five were unrelated and only for two a higher risk was observed. Washing of hands, domestic cleanliness (kitchen, living room, yard) and the use of a diaper/underclothes by the child had the strongest protective effect. Schooling (>3 years of primary school) and better economic position (possession of a radio) had a positive influence on general hygiene behaviour, education having a slightly stronger effect when a radio was present. Individual hygiene behaviour appeared to be highly variable in contrast with the consistent behaviour of the community as a whole. Feasible and appropriate indicators of hygiene behaviour were found to be domestic cleanliness and the use of a diaper or underclothes by the child.

Conclusion. A consistent effect of almost all hygiene practices on diarrhoea was detected, more schooling producing better hygiene behaviour. The high variability of hygiene behaviour at the individual level requires repeated observations (at least two) before and after the hygiene education in case one wants to measure the impact of the campaign on the individual.

Introduction

Childhood diarrhoea is a leading cause of morbidity and mortality in developing countries¹. As such it has stimulated much research that is aimed at understanding its etiology and evaluating preventive and therapeutic strategies. The Diarrhoeal Diseases Control Programme of the World Health Organisation has selected several areas which merit special consideration:² improvements in water availability and sanitation; improved nutrition, especially the promotion of breast feeding and better weaning practices; good personal and domestic hygiene; immunization against measles and rotavirus; and oral rehydration therapy (ORT).

Over the last decade several epidemiological studies have examined hygiene practices as risk factors for childhood diarrhoea³⁻¹³. Some of these practices identified as risk factors have subsequently been used as targets for behaviour modification through health education campaigns¹⁴⁻¹⁹. While hand washing has been the subject of many studies^{7,9,16,18,20-27}, other specific behaviours have received less attention^{13,28}.

Several investigations have used observation data, but little work has been performed to confirm their validity and repeatability²⁸. Two studies, one in Burkina Faso²⁹ and one in Bangladesh³⁰, compared responses from KAP (knowledge, attitudes, practices) questionnaires with observation data and found that results could be very different. Desirable practices were reported but not observed more times than they were observed but not reported. The studies claimed that data from direct observation are more valid than from questionnaires. However, repeated observations of a small sample of households in one of the studies²⁹ revealed a high variability of hygiene behaviour. The authors suggested that studies should be undertaken to assess this variability, and validity and repeatability of direct observation versus KAP questionnaires for measuring hygiene practice.

In this paper we present a study of the influence of hygiene practices on the incidence of diarrhoea in children aged <2 years, the relationship with maternal education and socio-economic position and the repeatability of direct observation of these practices. The study was carried out as part of an integrated programme of diarrhoea research in an area of rural Nicaragua. The initial investigation was a case-control study examining risk factors for diarrhoea. It was found that reduced availability of water and low maternal education were related to increased rates of diarrhoea³¹. Other studies examined the determinants of water quality and domestic water use^{32,33}. Subsequent work documented lay beliefs regarding the causes, treatment and prevention of diarrhoea, mothers' responses to diarrhoea, their willingness to use ORT³⁴ and possible explanations for Nicaragua's decline in infant mortality over the past 20 years³⁵. Results from this programme, e.g. the demonstration that poor availability of water was associated with a higher risk of diarrhoea, have informed and encouraged the development of prevention programmes such as production of rope pumps for water and sanitation programmes³⁶⁻³⁹ and other health promotion activities.

Materials and methods

The studies were conducted in Villa Carlos Fonseca, a rural municipality on the Pacific coastal plains of Nicaragua, 40 km from the capital Managua. Within its area of 500² kilometers there are approximately 32 000 inhabitants living in 38 different communities. It is almost an entirely agricultural society.

This investigation of the effect of hygiene practices on diarrhoea incidence is a prospective follow-up study of families who had participated in the initial case-control study that examined the links between diarrhoea and environmental sanitation³¹. A total of 2458 illness episodes were recruited to that study; 1229 bouts of diarrhoea plus a control group of 1229 illnesses not directly related to water supply and sanitation. As it was possible for children to be recruited on more than one occasion, and for different children within one family to be recruited, a total of 1402 families were included in the study and this group became the sampling frame for the prospective follow-up study of hygiene practices.

Of these 1402 different families, 585 mothers of infants had presented a child to the health facilities on two or more occasions with a diarrhoeal episode or with an illness serving as a control. Since cases of diarrhoea had been matched to controls at the outset, there was initially a probability of exactly 50% that any given episode was one of diarrhoea. This was effectively still the case with the reduced group of 585 families (of 1641 episodes of illness, 824 or 50.24% were diarrhoea). The cumulative binomial probability was calculated of observing more cases of diarrhoea than of control diseases within a given family. Using these probabilities 397 families were selected as 'high risk' or 'low risk' for diarrhoea and of these 172 also had a child <2 years old at the start of the follow-up period. Thus a total of 88 'high risk' and 84 'low risk' mothers were selected.

Before data collection was commenced in January 1989, a pilot study was performed with 41 households selected at random from a local population register. Observations lasting 3-4 hours were made by study assistants. They used a data recording form that was made intentionally open-ended in order to gain some idea of the range of practices likely to be encountered. From the results and experience obtained in this initial study a structured observation recording form was designed and pretested. Information was recorded on food hygiene (including baby's bottle hygiene), personal hygiene around study child, domestic hygiene, water hygiene and safe faeces disposal, as well as details on social, economic and educational status of the families, availability of water, and presence of latrines. A variety of different starting times for the observations were tried in order to find the period when most of the relevant activities were occurring.

Eight female field workers were recruited with at least 2 years of secondary school and who could not be distinguished from the local women. All had experience in child care and had managed household activities. The field workers attended a week long training workshop and were then accompanied and supervised by the study assistants for about three observations, until the latter were satisfied with their work. During the study every

fourth observation was overseen by one of the assistants. After each observation we reviewed the forms, checking in particular for inconsistencies and omissions, and discussing certain problems.

In each house, two periods of observations were carried out by the same field worker from about 8.30 am to 1 pm which is when most of the relevant domestic activities take place. The second observation was performed after 1 to 2 weeks and the observer had no access to the form of the first observation. Field workers were assigned randomly to a family and were blind to the diarrhoeal history of them. The purpose of the visit (observation of hygiene practices) was not revealed. Permission was given by the mothers to observe their children.

All observations were performed during the dry season. The incidence of diarrhoea in children aged <2 years was measured for 5 months. We started one month after the observations and included the rainy season when diarrhoea incidence in Nicaragua is highest³¹. The mothers were asked to fill out a daily diarrhoea calendar, especially designed for illiterate women. If there was more than one child aged <2 years, a diarrhoea calendar was given for each child. A photo of the child was taken and attached to the calendar. This also served as an incentive for the mother to take part in the study. A field worker visited the home each week and collected the completed calendars, reviewing them with the mothers to verify the accuracy of the record.

Coding and data entry was performed. Statistical packages (Epi Info and Lotus) were used for data analysis. Following the recommendations of MacClure and Willett⁴⁰, the repeatability of the dichotomous variables was measured using the unweighted Kappa score which takes into account the degree of concordance to be expected by chance alone⁴¹. Negative Kappa scores indicate less concordance than would be expected by chance. Positive Kappa scores between 0 and 1 suggest better concordance than expected by chance, with Kappa scores of 1 representing perfect agreement between the repeated measurements. For dichotomous variables, as are all variables of the hygiene behaviour presented, it is generally accepted that values <0.40 imply poor repeatability, 0.40 to 0.75 good repeatability, and values >0.75 indicate excellent repeatability⁴¹. Kappa scores are known to be biased however, when prevalence is either very high or very low^{42,43}. Differences in proportions were tested for statistical significance using the χ^2 statistic, and for trend using the Mantel-Haenszel extension to the χ^2 test.

Results

All 172 families could be observed. The observed children had a mean age of 13 months. The average household consisted of almost eight family members. Mothers had a mean age of 28 years and a mean education of 3 years (range from 0 to 11), with 23% being illiterate. Half of the houses were connected to electricity, 46% had a radio, 39% a concrete or tiled floor (as opposed to earthen), and only 7% a television.

Diarrhoeal incidence data were collected from all families on whom observations were made, in 85% of cases for the full 5 months, in a further 6% between 4 and 5 months, 2% between 3 and 4 months and in 7% for <3 months. The most important reason for leaving the incidence study prematurely was moving out of the study zone, furthermore two mothers were unwilling to continue filling out the diarrhoea calendar and two children died. Extensive analysis of the incidence data has been presented elsewhere⁴⁴.

In 54 of the 172 families, no diarrhoea was reported in the entire study period. These 54 mothers were compared with the 118 where at least one child had experienced one or more episodes of diarrhoea. An episode of diarrhoea was defined as four or more watery motions within a 24-h period. Mean age of children in the 'diarrhoea' group was 12 months; almost the same as that of children in the 'diarrhoea-free' group which was 13 months. Their breastfeeding and weaning profile at onset of study was exactly the same for both groups: 7% were never breastfed, 53% were being breastfed at the time the study began, and 40% had been weaned.

There was no difference in the duration of follow-up between families in the 'diarrhoea' group and those in the 'diarrhoea-free' group. Thus, the analysis of the relationship between diarrhoea with hygiene practice could be carried out using the full sample size of mothers, independently of how long they participated in the incidence study. Nevertheless, to see whether the different follow-up durations would influence the results, an analysis of the whole sample was compared with one excluding the 12 families who participated <3 months. Only slight differences were seen. The analyses presented here are with all participating mothers.

Table 1 presents the Kappa score for each hygiene practice and hygiene facility that could be observed twice. Since not all behaviours occurred during the visit, not every practice could be observed both times. Therefore the effective sample size varies for each hygiene practice studied. The Table also shows the percentage of mothers who performed the different 'good' hygiene practices during the first observation and the percentage who did this during the second one. The denominator is thus the number of mothers who could be observed twice on this particular hygiene practice.

Table 2 compares the frequency of 'good' practice between families in whom an episode of diarrhoea was recorded and those in whom no diarrhoea occurred. Significant differences were detected for washing hands before preparing food, and having a clean kitchen floor. Several other practices were of borderline statistical significance. Of the 46 'good' practices studied only two went in the opposite direction (neither of which were statistically significant), five were unrelated and for 39 the association was in the expected direction. Of these 46 'good' practices, 18 were consistently performed by more than half of the families which stayed 'diarrhoea-free' and 14 by more than half of them who had presented diarrhoea. In all categories hygiene behaviour was poor with the exception of water hygiene and safe faeces disposal. Hands were only consistently washed before preparing food and on none of the other occasions such as before eating and picking up the child.

Table 1. Kappa score and frequency of 'good' hygiene behaviour

'Good' hygiene practices	Families observed 2x	Observations First ¹	Second ²	Kappa
Food hygiene				
Hands washed before preparing food	113	79%	74%	0,47*
Hands washed when contaminated during cooking	87	33%	32%	0,66*
Fruit washed before eating	41	27%	22%	0,34
All food in covered pans or no food left	171	64%	64%	0,12
Utensils covered	171	8%	9%	0,66*
Hands of mother washed before eating	50	24%	28%	0,38
Hands of child washed before eating a meal	47	13%	11%	0,28
Hands of child washed before eating a snack	53	23%	11%	0,22
Child is assisted when eating	39	62%	56%	0,58*
Baby's bottle hygiene				
Hands washed before preparing baby's bottle	85	54%	59%	0,43*
Hands washed before giving bottle or breast feeding	103	25%	30%	0,35
Hands of child washed before drinking bottle	90	26%	28%	0,09
Bottle given by adult (against child holds bottle)	93	44%	40%	0,06
Bottle used is clean	84	96%	98%	-0,03
Bottle covered	91	67%	66%	0,43*
Personal hygiene around the child				
Hands washed before picking up child	153	16%	11%	0,24
Child taken care by own mother not by caretaker	170	81%	82%	0,59*
Clean appropriate place for child to stay	163	31%	26%	0,70*
Mother/caretaker attends the child all the time	164	42%	40%	0,58*
Domestic hygiene				
Table was cleaned within half hour after eating, cooking	138	62%	57%	0,31
Utensils cleaned within half hour after being used	142	45%	42%	0,31
Kitchen floor clean at onset of the observation	171	29%	29%	0,43*
Living room floor clean at onset of the observation	170	32%	34%	0,29
Barrier against animals in the house	171	4%	3%	0,48*
Chase dogs out of the house when they enter	95	11%	13%	0,18
Chase pigs out of the house when they enter	54	26%	30%	0,45*
Chase chickens out of the house when they enter	116	10%	8%	0,53*
Garbage organized in little heaps or not present	171	33%	32%	0,36
Garbage (if present) > 2 varas ³ from house	115	55%	56%	0,31
Water hygiene				
Cover on well is in use	122	21%	20%	0,65*
Vessel to draw water is clean	86	91%	94%	0,25
Vessel to store water is cleaned before filled with water	31	71%	71%	0,53*
> 2 water vessels in the house	170	40%	45%	0,46*
> 25 gallon water stored in the different vessels	170	50%	50%	0,69*
All water vessels for drinking water covered	162	56%	59%	0,38

Table 1 Continued
'Good' hygiene practices

	Families observed 2x	Observations First ¹	Second ²	Kappa
Safe faeces disposal				
No dirty paper in and around latrine	108	91%	91%	0,23
No faeces on slab of latrine	108	94%	98%	-0,03
No human faeces in the house	171	97%	98%	0,43*
No human faeces on the patio	171	93%	90%	0,36
No animal faeces in the house	171	80%	80%	0,28
No animal faeces on the patio	171	35%	33%	0,49*
No faeces <5 varas from house	157	59%	59%	0,42*
Child uses a diaper or underclothes	170	78%	77%	0,56*
Child defaecated and bottom was cleaned	22	86%	82%	0,15
Faeces removed from where deposited	22	91%	77%	0,18
Mother washes hands after visiting latrine	3	33%	33%	-
Water and sanitation facilities				
Good water source (tap or protected well)	172	65%	66%	0,96**
Distance to water source <150 varas	168	86%	84%	0,79**
Well has a cover on wellhead or cover is nearby	123	42%	42%	0,78**
Existence of a latrine	172	63%	65%	0,95**

1 Frequency of 'good' practice during first observation of all families in which practice could be observed on both visits.

2 Frequency of 'good' practice during second observation of all families in which practice could be observed on both visits.

3 1 vara = 0.8359 m.

Kappa <0.40 = poor repeatability.

Kappa 0.40-0.75 = good repeatability*.

Table 2. The proportion in which 'good' practice was observed on both visits in 'diarrhoea-free' and 'diarrhoea' families.

'Good' hygiene practices	Families observed 2x	'Diarrhoea-free' families (N=54)	Families with diarrhoea (N=118)	
Food hygiene				
Hands washed before preparing food	113	81%	60%	**
Hands washed when contaminated during cooking	87	29%	24%	
Fruit washed before eating	41	23%	7%	
All food in covered pans or no food left	171	39%	46%	
Utensils covered	171	9%	4%	
Hands of mother washed before eating	50	13%	14%	
Hands of child washed before eating a meal	47	13%	0%	
Hands of child washed before eating a snack	53	10%	3%	
Child is assisted when eating	39	55%	46%	
Baby's bottle hygiene				
Hands washed before preparing baby's bottle	85	58%	36%	*
Hands washed before giving bottle or breast feeding	103	25%	10%	*
Hands of child washed before drinking bottle	90	16%	6%	
Bottle given by adult (against child holds bottle)	93	27%	34%	
Bottle used is clean	84	96%	93%	
Bottle covered	91	60%	52%	

Table 2 Continued

'Good' hygiene practices	Families observed 2x	'Diarrhoea-free' families (N=54)	Families with diarrhoea (N=118)	
Personal hygiene around the child				
Hands washed before picking up child	153	6%	4%	
Child taken care by own mother not by caretaker	170	76%	75%	
Clean appropriate place for child to stay	163	24%	21%	
Mother/caretaker attends child all the time	164	36%	28%	
Domestic hygiene				
Table was cleaned within half hour after eating, cooking	138	51%	39%	
Utensils cleaned within half hour after being used	142	33%	24%	
Kitchen floor clean at onset of the observation	171	33%	9%	***
Living floor room clean at onset of the observation	170	24%	14%	*
Barrier against animals in the house	171	4%	1%	
Chase dogs out of the house when they enter	95	7%	2%	
Chase pigs out of the house when they enter	54	24%	14%	
Chase chickens out of the house when they enter	116	6%	5%	
Garbage organized in little heaps or not present	171	26%	15%	*
Garbage (if present) > 2 varas ^a from house	115	49%	34%	
Water hygiene				
Cover on well is in use	122	18%	13%	
Vessel to draw water is clean	86	89%	87%	
Vessel to store water is cleaned before filled with water	31	80%	58%	
> 2 water vessels in the house	170	49%	42%	
> 25 gallon water stored in the different vessels	170	49%	39%	
All water vessels for drinking water covered	162	49%	39%	
Safe faeces disposal				
No dirty paper in and around latrine	108	84%	85%	
No faeces on slab of latrine	108	95%	92%	
No human faeces in the house	171	100%	94%	
No human faeces on the patio	171	93%	84%	
No animal faeces in the house	171	67%	68%	
No animal faeces on the patio	171	30%	19%	
No faeces <5 varas from house	157	53%	42%	
Child uses a diaper or underclothes	170	80%	66%	*
Child defaecated and bottom was cleaned	22	83%	69%	
Faeces removed from where deposited	22	83%	69%	
Mother washes hands after visiting latrine	3	-	33%	
Water and sanitation facilities				
Good water source (tap or protected well)	172	65%	64%	
Distance to water source < 150 varas	168	85%	81%	
Well has a cover on wellhead or cover is nearby	123	41%	35%	
Existence of a latrine	172	69%	60%	

a 1 vara = 0.8359 m.

Significance tests compare proportions performing the 'good' practice of the 'diarrhoea-free' and the 'diarrhoea' group

* $P=0.05-0.1$; ** $P<0.05$; *** $P<0.001$.

Table 3. The proportion of 'diarrhoea-free' families according to whether 'good' practice was observed twice, once or not at all.

'Good' hygiene practices	Families observed 2x	Twice ^a	Once ^a	Not at all ^a
Food hygiene				
Hands washed before preparing food	113	39%	18%	19% **
Hands washed when contaminated during cooking	87	36%	38%	29%
Fruit washed before eating	41	60%	30%	27%
Hands of mother washed before eating	50	29%	42%	23%
Hands of child washed before eating a meal	47	100%	29%	29%
Hands of child washed before eating a snack	53	67%	42%	34%
Baby's bottle hygiene				
Hands washed before preparing baby's bottle	85	39%	25%	16% **
Hands washed before giving bottle or breast feeding	103	53%	26%	31%
Hands of child washed before drinking bottle	90	50%	31%	22% *
Bottle given by adult (against child holds bottle)	93	23%	33%	29%
Bottle used is clean	84	28%	20%	-
Bottle covered	91	31%	26%	21%
Personal hygiene around the child				
Hands washed before picking up child	153	43%	26%	32%
Domestic hygiene				
Table was cleaned within half hour after eating, cooking	138	37%	22%	33%
Utensils cleaned within half hour after being used	142	37%	29%	27%
Kitchen floor clean at onset of the observation	171	62%	35%	22% ***
Living room floor clean at onset of the observation	170	45%	40%	23% **
Barrier against animals in the house	171	67%	17%	32%
Chase dogs out of the house when they enter	95	67%	38%	25% *
Chase pigs out of the house when they enter	54	44%	33%	27%
Chase chickens out of the house when they enter	116	33%	44%	29%
Garbage organized in little heaps or not present	171	45%	35%	25% **
Garbage (if present) > 2 varas ^b from house	115	39%	31%	19% *
Water hygiene				
> 2 water vessels in the house	170	35%	35%	24%
> 25 gallon water stored in the different vessels	170	36%	19%	31%
All water vessels for drinking water covered	162	38%	29%	30%
Safe faeces disposal				
No animal faeces in the patio	171	42%	18%	33%
No faeces < 5 varas from house	157	37%	25%	29%
Child uses a diaper or underclothes	170	36%	27%	16% **
Child defaecated and bottom was cleaned	22	31%	20%	0%
Faeces removed where deposited	22	31%	20%	0%

^a Number of times 'good' practice was observed.

^b 1 vara = 0.8539 m.

Differences in proportions tested for trend (different levels of performing 'good' practices: twice, once, not at all)

* $P=0.05-0.01$; ** $P<0.05$; *** $P<0.0001$.

Table 3 presents the proportion of 'diarrhoea-free' families among those in whom 'good' practice was observed twice, once and not at all. Mothers of the three groups together form the effective sample size. In order to limit the amount of data, we only show those hygiene behaviours which were most closely related to diarrhoea in Table 2. In general, the children in families where the 'good' practice was performed on both visits had lower rates of diarrhoea than those where it was observed on just one visit, and these had lower rates than children in families where the 'good' practice was not realized on either visit. Thus a clear trend is seen of decreasing number of 'diarrhoea free' families with increasing poor hygiene.

Table 4 gives the proportions of 'good' behaviour on both occasions compared to two levels of education: 'low' when schooling is ≤ 3 years of primary school (54%) and 'good' when >3 years (46%). Of the 46 'good' practices studied, 32 were more often performed by mothers with 'good' schooling than by those with 'low' schooling, 13 less and for one the proportions were the same. Mothers with 'good' education covered their food, baby's bottle and water vessels and washed their hands before giving bottle or breast feeding significantly more often than those with lower schooling.

Table 4. The proportion in which 'good' practice was observed on both visits according to level of schooling.

'Good' hygiene practices	Families Observed 2x	All + / +	Level of schooling	
			'Good' + / +	'Low' + / +
Food hygiene				
Hands washed before preparing food	113	67%	69%	65%
Hands washed when contaminated during cooking	87	25%	26%	25%
Fruit washed before eating	41	12%	10%	14%
All food in covered pans or no food left	171	31%	42%	23% ***
Utensils covered	171	6%	7%	5%
Hands of mother washed before eating	50	14%	17%	11%
Hands of child washed before eating a meal	47	4%	4%	4%
Hands of child washed before eating a snack	53	6%	4%	8%
Child is assisted when eating	39	49%	52%	44%
Baby's bottle hygiene				
Hands washed before preparing baby's bottle	85	42%	51%	35%
Hands washed before giving bottle or breast feeding	103	15%	24%	7% **
Hands of child washed before drinking bottle	90	9%	12%	6%
Bottle given by adult (against child holds bottle)	93	32%	31%	33%
Bottle used is clean	84	94%	100%	89% *
Bottle covered	91	54%	66%	43% **
Personal hygiene around the child				
Hands washed before picking up child	153	4%	3%	6%
Child taken care by own mother not by caretaker	170	76%	78%	73%
Clean appropriate place for child to stay	163	22%	24%	20%
Mother/caretaker attends child all the time	164	31%	30%	31%

'Good' hygiene practices	Families Observed 2x	All + / +	Level of schooling	
			'Good' + / +	'Low' + / +
Domestic hygiene				
Table was cleaned within half hour after eating, cooking	138	43%	46%	41%
Utensils cleaned within half hour after being used	142	27%	34%	21% *
Kitchen floor clean at onset of the observation	171	17%	22%	13%
Living room floor clean at onset of the observation	170	17%	22%	14%
Barrier against animals in the house	171	2%	1%	2%
Chase dogs out of the house when they enter	95	3%	6%	2%
Chase pigs out of the house when they enter	54	17%	13%	19%
Chase chickens out of the house when they enter	116	5%	2%	7%
Garbage organized in little heaps or not present	171	18%	19%	17%
Garbage (if present) > 2 varas ^a from house	115	38%	41%	36%
Water hygiene				
Cover on well is in use	122	19%	18%	19%
Vessel to draw water is clean	86	87%	88%	86%
Vessel to store water is cleaned before filled with water	31	19%	23%	17%
> 2 water vessels in the house	170	44%	49%	40%
> 25 gallon water stored in the different vessels	170	42%	47%	38%
All water vessels for drinking water covered	162	43%	52%	35% **
Safe faeces disposal				
No dirty paper in and around latrine	108	84%	78%	92% **
No faeces on slab of latrine	108	93%	90%	96%
No human faeces in the house	171	96%	97%	95%
No human faeces on the patio	171	87%	84%	89%
No animal faeces in the house	171	68%	69%	67%
No animal faeces on the patio	171	87%	84%	89%
No faeces < 5 varas from house	157	45%	51%	41%
Child uses a diaper or underclothes	170	70%	77%	65% *
Child defaecated and bottom was cleaned	22	73%	78%	69%
Faeces removed from where deposited	22	96%	100%	92%
Mother washes hands after visiting latrine	3	33%	50%	0%
Water and sanitation facilities				
Good water source (tap or protected well)	172	65%	77%	55% ****
Distance water source < 150 varas	168	82%	94%	74% ****
Well has a cover on wellhead or cover is nearby	123	37%	52%	28% ***
Existence of a latrine	172	63%	80%	50% ****

a 1 vara = 0.8359 m.

Significance tests compare proportions performing the 'good' practice of the families with 'good' and with 'low' schooling

* $P=0.05-0.1$; ** $P<0.05$; *** $P<0.01$; **** $P<0.005$.

When analysing the association between education and the incidence of diarrhoea we saw a borderline statistically significant relation: of the 12 mothers with >6 years of schooling 58% did not present diarrhoea during the entire study, meanwhile only 29% of those with ≤6 years of education stayed 'diarrhoea-free' ($P=0.06$). Two socioeconomic indicators turned out to be important in this setting: type of floor and the presence of a radio. Of families with a 'good' floor plus a radio 48% stayed 'diarrhoea free'; of families with a 'good' floor or a radio 35%; and of those with an earthen floor and no radio only 16% (P for trend < 0.001). Education was strongly related to these socioeconomic indicators: of families with a 'good' floor plus a radio 68% had >3 years of schooling; of families with a 'good' floor or a radio 40%; and of those with an earthen floor and no radio 35% (P for trend < 0.01).

Table 5. The proportion of families in which 'good' practice was observed on both visits according to education and presence of a radio.

'Good' hygiene practices	Families observed 2x	No radio present		Radio present	
		'Low' ^a	'Good' ^b	'Low' ^a	'Good' ^b
Food hygiene					
Hands washed before preparing food	113	69%	65%	58%	72%
Baby's bottle hygiene					
Hands washed before preparing baby's bottle	85	28%	41%	43%	59% *
Domestic hygiene					
Kitchen floor clean at onset of the observation	171	14%	18%	13%	26%
Living room floor clean at onset of the observation	171	14%	18%	13%	26%
Garbage organized in little heaps or not present	171	16%	15%	20%	23%
Safe faeces disposal					
Child uses a diaper or underclothes	170	58%	69%	75%	85% **

a 'Low' schooling is ≤3 years of schooling.

b 'Good' schooling is >3 years of schooling.

Differences in proportions tested for trend (for different levels of education and socio-economic position)

* $P < 0.05$ ** $P < 0.005$.

In order to have an idea in how far economic position influences the effect of education on hygiene practices, we analysed those behaviours that were statistically significant related to diarrhoea. All 'good' hygiene practices were most frequent in families where the mother had >3 years of schooling and where a radio was also present (Table 5).

Discussion

We investigated the influence of a large number of hygiene practices on the transmission of diarrhoea. This knowledge is necessary to develop successful hygiene education with

appropriate messages. We also validated the technique of direct observation of hygiene behaviour. This information is needed to be able to evaluate the impact of hygiene campaigns on this behaviour.

Tables 2 and 3 give an impression of the effect of each hygiene practice separately. For some of the practices the effective sample size was very small and results should be interpreted with caution. Also, the large number of statistical tests performed means that one can expect several significant results to occur through chance alone. Almost all hygiene practices studied such as hand washing, food and water hygiene, cleaning food preparation area, general cleanliness and safe faeces disposal showed a clear relationship with diarrhoea. The families without diarrhoea were the ones who practiced 'good' behaviours more frequently and more consistently. Presumably because of the small sample sizes, only the more pronounced hygiene behaviours were statistically significant on their own. If one looks however at the overall picture, it is striking how consistent the trend is of increasing diarrhoea incidence with poorer hygiene behaviour.

We also found a trend that the proportion of 'diarrhoea-free' families increases with the number of times that a 'good' practice was observed (Table 3). This must be considered as a strong indicator of the importance of that specific hygiene practice in the transmission of diarrhoea. It was statistically significant for different types of hand washing, several practices within the category of domestic cleanliness and the use of a diaper or underclothes by the child. These practices might therefore be considered as targets for modification through health education campaigns. For each of these, earlier studies^{3-30,45,53} have also shown an effect on diarrhoea.

The facilities for water and sanitation have, of course, an excellent Kappa score; the few differences observed were caused by mothers who moved houses between the two observations. There was no less diarrhoea in families with piped-water or a protected hand-dug well than in those using untreated river water, so water quality does not seem to be a major risk factor in this setting. Distance to the water source and amount of water stored in the house (proxies for water consumption) seemed to have a weak association, as we had already found in the earlier study³¹.

As one can observe in Table 2, the existence of a latrine has a beneficial effect, but this has been noticed in many other studies. Mothers' behaviour with regard to disposal of children's stools is at least as important^{8,17,45}. In rural Nicaragua children aged <5 years only infrequently use a latrine because they are afraid of the 'black hole' while mothers regard their faeces as benign. Consequently, cleaning occurs more for cosmetic/aesthetic reasons than because of mothers' knowledge about transmission routes. This is also true for hand washing. As we discovered in the earlier study, knowledge about the importance of washing hands amongst the general population is quite prevalent, but limited to the hands of the mother when preparing food or baby's bottle; practices which also had a good Kappa score. Washing the child's hands before eating and the mother's before picking up the child are almost non-existent. This normative concept of mothers' behaviour performing the 'good' practice because it is socially acceptable behaviour, rather than effective in the prevention

of diarrhoea has also been described elsewhere^{28,47,48} and fits well with Fishbein and Ajzen's Theory of Reasoned Action⁴⁹.

A complicated relation has been described between socio-economic status, education, cultural factors and hygiene practices. Recent research has suggested that, in the US, affluence and education in the last decade of the nineteenth century made little difference to child mortality, until scientific knowledge showed households how to reduce dangers to their health¹. Since individuals with more education acquire and use new information more quickly, this emphasis on knowledge helps to explain the large differences in child mortality by mothers' education observed in developing countries today^{1,35}. Most studies on hygiene show that practices improve as education (and affluence) increases, although in some studies only knowledge, and not practices, increased²⁸. Several studies^{28,50-54} found that the presence of certain material resources such as a latrine, water and soap should be considered as preconditions for a change in hygiene behaviour through health education. Without these preconditions, although knowledge exists, the 'good' practice simply cannot be performed consistently; meanwhile social and cultural factors may have a reinforcing or restraining influence.

In our study no pronounced differences in hygiene behaviour were found for education, probably because this rural population is quite homogeneous for schooling; only 12 mothers had more than primary school education. Nevertheless differences were seen and in the expected direction -more schooling producing better hygiene behaviour, this being slightly stronger in the presence of a radio.

Several transmission routes of diarrhoea usually coexist⁵⁵. Our results suggest that some routes, such as hand washing play a more important role than others. Of course the performance of one 'good' hygiene practice will have a strong correlation with the realization of other 'good' practices and although the practice itself may only be related weakly to diarrhoea transmission, it could be indicative for other behaviour which plays a more important role in the transmission.

What would be a good indicator for hygiene behaviour in this setting? Indicators should at least be representative of general hygiene behaviour; easy to observe (no high education of field worker necessary); not costing much time (easy to observe during a certain time period); unambiguous (limited interobserver differences); almost all mothers can be observed for this particular practice (thus producing little missing data); not uniformly performed (e.g. >10-20% or <80-90% realizes the 'good' practice); accessible for the field worker (not necessary to enter bedrooms, etc). From the results of Tables 2 and 3 one can deduce that indeed hand washing has a relation with the transmission of diarrhoeal diseases, but only one of all types of hand washing had an effective sample size of more than 150 mothers and that one (before picking up the child) was performed by less than 10% of families, leaving us with none of the different types of hand washing being an appropriate indicator for general hygiene behaviour.

In our case the cleanliness of the floor of kitchen and living room, the disposal of rubbish

and whether the child uses a diaper or underwear seem to be good indicators for the measuring of hygiene behaviour. These practices fulfill almost all requirements: they have a clear effect on diarrhoea transmission; are easy to observe; do not cost much time; all mothers can be observed on this particular practice; >15% and <80% of mothers perform the 'good' behaviour and they are accessible for the field worker. Although cleanliness of the kitchen and living room floor are not completely unambiguous, training and especially frequent supervision of the field workers can limit the interobserver differences. Whether this finding can be generalized would require another study, preferably on another continent, although results of all hygiene studies together on three different continents^{3-30,45-48,50-53,55} have given remarkably similar results (e.g. domestic cleanliness [kitchen, living room, yard] was often found to have an effect on diarrhoea incidence^{5,8,11,12,17,18,45}).

It was not feasible to combine hygiene practices in possible models and composite hygiene scores since almost none of the hygiene practices could be observed for all mothers during both observations. Excluding all missing data would leave us with a very small sample size and possibly a high selection.

The results of the Kappa score in our study present a low repeatability of observations of hygiene practices, less than half has a good repeatability and none an excellent score. This high variability at the individual level has been found in other studies^{28,29}. Although individual practices are variable, the study in Burkina Faso²⁹ which observed 10 families on six separate occasions concluded that analysis of these six observations revealed a pattern of repeatability consistent with that suggested by a comparison of two observations. In Table 3 one can observe that apparently two observations were sufficient to group mothers in such a way that a trend in diarrhoeal incidence related to the level of hygiene could be uncovered. This trend would not have been detected if we had analysed both observations independently. As expected, the frequency with which the community as a whole performed the 'good' practice was about the same during the second observation as during the first.

Conclusions

This was the first investigation to study simultaneously a high number of hygiene practices hypothesized to relate to the transmission of diarrhoeal diseases. A consistent effect of almost all hygiene practices on the diarrhoeal disease incidence was detected, even if this was statistically significant in relatively few cases. More schooling produced better hygiene behaviour, this being slightly stronger in the presence of a radio.

Relatively few practices were found to serve as an indicator for general hygiene behaviour related to the transmission of diarrhoea. These were cleanliness of the kitchen and living room floor, disposal of rubbish and whether the child uses a diaper or underclothes.

The high variability of hygiene behaviour at the individual level requires repeated observations (at least two) -before and after the hygiene education in the event one wants to measure the impact of the campaign on the individual. The stable occurrence of practices in the

community as a whole means that one observation before and one after the health education campaign should be sufficient to monitor its effect on the overall behaviour.

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Section 4.5.

Childhood diarrhoea in rural Nicaragua: beliefs and traditional health practices

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Abstract

In Nicaragua, the principal cause of infant mortality is diarrhoea, which is responsible of 40% of these deaths annually. This statistic reflects the low usage of health services and of oral rehydration therapy (ORT). Several studies were carried out in the Villa Carlos Fonseca municipality with the aim of creating programmes to improve this situation. This report describes two of those studies: one is ethnographic in character and was carried out in 1989, and the other epidemiological and was carried out in 1990. Both have as their aim, the gathering of information on traditional health beliefs and practices and their influence on the way in which mothers responded to their children's diarrhoeal illness. The ethnographic study involved interviewing 70 mothers with an average age of 28 years who had children under two years of age. The children represented two groups: one which was at a high risk of contracting diarrhoea and one which was at a low risk. The objectives included obtaining knowledge on the traditional taxonomy of diarrhoea, the perception of risk and the types of treatment being used. In the epidemiological study, 392 mothers of over 14 years of age participated, each with one or more children under the age of five, 216 of whom had diarrhoea in the two weeks preceding the survey. The objectives were to describe local health beliefs and practices and to determine the incidence of the types of diarrhoea according to the diagnoses made by the mothers.

At least 12 types of diarrhoea were identified, for which terms with names such as "empa-cho" and "sol de vista" were used. In the majority of cases, the mothers had more confidence in folkloric treatments that they themselves or the traditional midwives or healers (curanderas) applied, than in the services provided by the health centres. This attitude limited their use of health services and of ORT, although it was observed that, in certain cases, mothers used traditional treatments in combination with those of western medicine. There was a direct correlation, though non-significant, between the level of formal education of the mothers and the frequency with which they visited the health center.

The authors suggest studying the effects of massage, herbal baths and other traditional treatments in order to evaluate their effectiveness and adapt them, to the extent possible, to "modern" medicine. Health services providers should become familiar with traditional nomenclature and beliefs in order to improve their communication with mothers, and reorient harmful practices to obtain better results in programmes for the prevention of infant diarrhoea.

Introduction

Diarrhoea is one of the main causes of infant morbidity and mortality in developing countries¹. In order to reduce this problem, the World Health Organization (WHO) has selected the following areas for special consideration: improvements in child nutrition, especially through the promotion of breast feeding and better weaning practices; improvements in potable water availability and sanitation; personal and domestic hygiene; immunization against measles in order to prevent diarrhoea associated with this disease and the improvement of the anti-rotavirus vaccine which is still in the experimental stage².

Oral rehydration therapy (ORT), which consists of the administration of oral fluids - prepared with the appropriate homemade recipes; with commercially available oral rehydration salts; or those distributed by the WHO - can not be substituted in the treatment of diarrhoea. The systematic use of this therapy in health centres and in the home will undoubtedly contribute to the reduction of the rate of mortality caused by diarrhoea³. In rural zones, and more particularly in those that are isolated, the knowledge of preventive measures and of proper treatment of infant diarrhoea in the home, especially with ORT, can mean the difference between life and death.

During the last decades, several ethnographic studies on diarrhoeal disease in children of various socio-cultural environments have been carried out⁴⁻¹⁵. These studies have led to the analysis of the relationship between popular beliefs about diarrhoea and the behavior of mothers when faced with this illness in their children, including their inclination to use ORT. The results indicate that a modification of traditional practices in the home is necessary, but also note the importance of taking into consideration folkloric beliefs in planning campaigns to promote ORT and preventive measures directed at mothers of small children. Furthermore, in several epidemiological studies it was noted that some of these beliefs, attitudes and health practices may, in fact, increase the risk of diarrhoea. It is essential to have in-depth knowledge of these factors and seek ways for modifying them through health education programmes and other pertinent interventions¹⁶⁻¹⁹.

In Nicaragua, where ORT began to be promoted in the mid 1970's and where its use increased as of 1979²⁰, a continuous decrease in the rate of infant mortality has been observed²¹. Nonetheless, the present annual rate of 56 deaths per 1000 live births is unacceptably high¹, mainly due to diarrhoea which causes 40% of these deaths²². Among the factors that could be related to this situation are: in case of diarrhoea not always the available health services are used; often these services are sought too late; and the use of ORT has not become generalized enough.

In societies with traditional cultures, mothers' decisions on the treatment of their children suffering from diarrhoea are influenced by folkloric beliefs and customs. Taking this factor into consideration, in 1986, in the rural municipality of Villa Carlos Fonseca, a research programme was implemented as a basis for elaborating community projects for the prevention and treatment of childhood diarrhoea. This programme was financed by

the WHO Work Group on Diarrhoea and by The Leverhulme Trust of Great Britain, and executed in collaboration with the Nicaraguan Ministry of Health, the Nicaraguan Institute for Water and Sewage, the Nicaraguan University of Engineering and the Foundation for Social and Economic Development of Rural Areas (DESEAR) in Villa Carlos Fonseca²³⁻³⁰.

Through a first case-control study in 1986, in which 1402 families participated, risk factors directly related to the high incidence of childhood diarrhoea were identified. The most significant risk factors were low maternal education and low availability of water²³. Based on this information, a project was elaborated in order to educate mothers in the principles of hygiene and to develop rope pumps in order to obtain water from hand-dug wells. Since then, the rope pump has become recognized as an appropriate technology and is presently being used in water and sanitation programmes in rural Nicaragua. This technology has been transferred to other developing countries such as Honduras and El Salvador²⁴⁻²⁶.

As a follow-up, in 1989, a prospective study was designed to clarify the relationship between mothers' hygiene practices and the incidence of diarrhoea in their children. A group of 172 mothers were selected randomly from the 1402 families who participated in the case-control study. The only criterion used in this selection was that mothers had children under the age of two years: half of the mothers with a history of frequent diarrhoea in their children and the other half with a history of low diarrhoea incidence in their children²⁹. This study led to the identification of the most relevant of maternal practices related to diarrhoea and, based on these, permitted an improved design of the project for educating the population on hygiene principles. It was also decided to begin another project to introduce hand washing in schools.

This report presents the results of two other studies related to the previously mentioned investigations. The first, ethnographic in nature, was carried out in 1989 as part of the prospective investigation already described here, with the aim of obtaining information about traditional taxonomy, diagnoses and treatments for childhood diarrhoea used in the area. The second was a epidemiological survey carried out in 1990, with the aim of quantifying beliefs and treatment practices and determining the incidence of the types of diarrhoea, according to the traditional diagnosis made by mothers in the home.

Materials and methods

Local context

The municipality of Villa Carlos Fonseca, where the studies were carried out, is located 30 kilometers from Managua, on the pacific coastal plains of Nicaragua. Its population is approximately 30,000, distributed among 38 communities. The local economy is dependent on agricultural production. Health resources available to the inhabitants of the municipality include one health center and six health posts, with six doctors, one den-

tist, one pharmacist, two nurses, 12 nurse's aids and a health educator. There are also 80 midwives who also work as traditional healers.

The ethnographic investigation

Ethnographic research was carried out from March to June of 1989, as part of the prospective investigation which complemented the case-control study of 1986. Of the 172 mothers in the prospective study, 70 were randomly selected from a list of names to participate in the ethnographic research.

The participants had an average age of 28 years: 24% of them had never attended school, 67% had attended primary school from 1 to 6 years and only 9% had attended, though not completed, secondary school.

A semi-structured interview was used to gather information. A guide was designed, based on literature related to the topic and information provided by people who had thorough knowledge of the conditions of the community, such as traditional midwives or healers, community leaders, and health and education personnel. A locally used taxonomy of the various types of diarrhoea was defined. In the semi-structured interviews, mothers were asked to verify the different types of diarrhoea as defined and it was sought to determine their knowledge and beliefs related to causes, symptoms and treatments depending on the types; their perception of risks; their use of health resources (official services or traditional midwife or healer); preventive practices and use of ORT.

The interviewers - a schoolteacher and a midwife, both mothers and residents of the municipality of Villa Carlos Fonseca - were fully trained by project personnel, emphasizing the need for objectivity toward folkloric beliefs. The two women had been interviewers in previous studies and had participated in the discussions related to the definition of the locally used taxonomy. Two students of Health Education from the University of Limburg (the Netherlands) observed the interviews as part of their study programme.

Data on age, education and socio-economic aspects of participants were taken from the prospective study, which has not yet been published completely²⁹, and therefore are not included in this report.

The epidemiological investigation

The epidemiological study was included in the survey on morbidity and mortality, applied to 500 homes in the municipality of Villa Carlos Fonseca. These homes were randomly selected, by choosing every tenth house of the 5.000 located in the 38 communities. This survey was carried out from June to August of 1990, which are the months of the highest incidence of diarrhoea during the year²³⁻³⁰.

Diarrhoea was defined as a period of one or more days, of three or more watery bowel movements. The interview for mothers with children under the age of five years included aspects related to the presence and type of diarrhoea, care of the child in the home, type of help sought and use of ORT. The interviews were carried out by four female res-

idents of the municipality who had experience with previous studies and who were also trained by project personnel.

All women over the age of 14 years were interviewed and were asked the cause of death of any children who had died. If the death had been caused by diarrhoea, they were asked to identify the type of diarrhoea.

Results

The Ethnographic Study

At least 90% of the mothers were familiar with all of the types of diarrhoea according to the popular taxonomy, but only 77% knew about "bad stomach" and 74% about dysentery. In the following section an abstract is provided of the description made by the interviewed mothers with respect to each type of diarrhoea and the use of ORT.

Types of diarrhoea

The statistics presented here are descriptive. The base for percentages is always given for the group of women who recognized and could comment on the type of diarrhoea in question.

Empacho. Empacho occurs when food or beverage sticks onto the wall of the stomach and rots. It can present a danger to the child's life. It causes a watery and foul-smelling, white or yellow diarrhoea, and is associated with swelling and pain in the stomach. It may be accompanied by fever, vomiting and nausea, although some mothers explicitly mentioned absence of these symptoms.

According to 82% of the mothers, empacho should be treated with laxatives to clean the stomach and remove the material causing the diarrhoea. Among treatments used are a laxative oil taken with or without lemon juice, and milk of magnesia. Other treatments include "sobada", a massage which is thought to unblock the stomach. A few mothers also mentioned ORT, antibiotics, herbs and antacids. Generally a mother or traditional midwife or healer was the appropriate person to treat empacho.

Infection. Infection is caused by a lack of hygiene. It is life-threatening and produces a watery, yellow or green diarrhoea, occasionally with mucous or blood. It is also accompanied by fever and vomiting.

In this case, 81% of the mothers mentioned treatment with antibiotics and 42% spoke of ORT. Almost all (96%) said that infection should be treated by a doctor.

Sol de vista (mal de ojo). This is caused by the child having eye contact with people who are in what is considered to be a hot state. As examples of such people; 59% of the mothers mentioned workers who had worked all day in the fields; 54% mentioned pregnant women; 49% people with a penetrating gaze; 46% drunks and people with hangovers;

17% menstruating women; and 7% young women. Sol de vista can be life threatening.

This diarrhoea is green, with mucus, and defecation is painful. The child has a high fever and headache, cries and has sad or 'dirty' eyes.

Treatment requires the presence, symbolic or real, of the person who caused the condition. For example, 53% recommended that the child be wrapped in the sweaty shirt of the person who caused the diarrhoea and 24% recommended that the child be held in the lap of this person. According to 39% of the mothers, this type of diarrhoea should be treated with alcohol or herb baths. Other suggestions included the application of father's urine on the child's head; the application of a mixture of saliva and breast milk; stomach massage; and a hair being wrapped around one of the child's wrists. Only two women (3%) mentioned ORT and one recommended taking the child to a doctor.

Sol de cielo (pujo de sol). This "diarrhoea of the sun" is attributed to several causes: heat and exposure to the sun (92%), hot weather (11%) and heat in the home (11%). It is not considered dangerous. This diarrhoea is green and painful, with mucus and fever.

According to 72% of the mothers, treatment consists of baths with alcohol, herbs, wood and nut oils, or very cold water. Fruit drinks (frescos) were recommended by 17%. In general, the mothers themselves treat children with sol de cielo, though 20% preferred to take them to a traditional midwife or healer. Only one suggested seeing a doctor.

Diarrea de movimiento. This diarrhoea is considered part of normal development. It occurs when the child is teething (92%), starting to crawl (62%) or walk (89%). It is not considered dangerous and has no specific symptoms.

According to the majority (54%) of the mothers, this diarrhoea does not require any specific treatment, but 16% thought it was necessary to visit the health center. Some women mentioned antibiotics (8%), fruit drinks (5%), ORT (3%) and rice water (3%).

Worms and parasites. These cause two types of diarrhoea and can be life-threatening. They are considered to be almost identical, except that they can be distinguished by their size. Worms are easily detected in the child's stool, but parasites are invisible. Bad hygiene is associated with diarrhoea caused by parasites, but seldom with that caused by worms. Worms become dangerous only when they are activated by a full moon, foods such as milk and sugar, and fever (worm fever), which causes the worms to leave the stomach and circulate through the body.

The stool contains a gritty element (chingaste) in its generally liquid composition. Common symptoms are fever, vomiting, and a painful stomach which may be swollen. The child's eyes may remain open while sleeping. The worms can cause itching of the nose, face or stomach, and grinding of the teeth. Mothers give children medication for parasites each time they present these symptoms.

The majority (92%) of the mothers mentioned mebendazol, piperazine, or metronidazole, but also herbs such as 'epazote' or wintergreen (20%) and garlic (10%), which cause worms that are circulating in the body to return to the stomach, where they can be expelled by medicines. Five women (8%) mentioned the use of ORT when parasites are detected, but none mentioned it for worms. In the case of worms, 62% considered a visit to the doctor necessary, and 93% considered this necessary for parasites.

According to 39%, self-treatment can also be used, especially for worms. The first step is to administer substances to calm or regroup the worms, then the patient is taken to the health center. Only two mothers (3%) mentioned the traditional midwife or healer.

Bad stomach. The cause of bad stomach is bad or badly prepared foods (51%), milk (23%), food in general (11%), or eating when angry (4%). It is not a danger to the child's life. The diarrhoea is watery, with stomach pains and sometimes accompanied by vomiting. Ten mothers insisted that it did not cause a fever, while seven stated that it did.

Half of the mothers suggested milk of magnesia, with or without lemon, or a laxative oil to treat this diarrhoea, 34% recommended other antacids. In 60% of the cases, the mother administered the treatment, although 34% mentioned a visit to the health center and two (4%) to the traditional midwife or healer.

Dysentery (desgaste). There was no consensus on the cause of this diarrhoea, but bad hygiene, factors related to food and beverage preparation and consumption were mentioned. Almost half of the mothers were unable to identify some cause. Dysentery is seen as an end-stage condition following a prolonged diarrhoea due to infection or sometimes empacho. It is seldom related to any other type of diarrhoea. It is the most dangerous type of diarrhoea and the less known. It is watery and bloody, and may be accompanied by mucus and sometimes by vomiting and fever.

Only 58% of the women recommended any type of treatment, and ORT was the most frequently (60%) mentioned. Some mentioned antibiotics, fruit drinks, and aluminum preparations, as well as baths. The great majority (90%) stated that the person most appropriate for treating dysentery was the doctor.

Fallen fontanelle. 90% believed that this condition could be caused by falls, meanwhile 6% mentioned the child's head falling back suddenly and 1.5 to 3% suggested the rapid removal of the bottle; blows to the head; violent coughing; being held in the wrong way; having received a blow while eating; or drinking from a bottle with a nipple that was too hard. Almost half (45%) thought that diarrhoea itself caused the fallen fontanelle and considered this condition to be fatal.

Treatments mentioned were pushing the roof of the mouth upwards with the thumb (79%); applying massage (44%); holding the baby upside down and hitting it on the bottom of its feet (38%); a bath with oil (5%); laxatives (2%); and giving herb infusions (2%). The massage used in this case is different from that which is used for empacho. It

begins with the hands and feet and moves to the center of the body. It is believed that this practice lifts the fallen fontanelle, as it "closes the body". Of the mothers 91% recommended a visit to the traditional midwife or healer; 11% a visit to the health center; and 5% the administration of home remedies.

Attitudes towards oral rehydration therapy

Of the mothers who were interviewed, 88% said they thought oral rehydration therapy was an appropriate treatment for diarrhoea. Some of their reasons included that it cleaned out or refreshed the stomach (53%), that it eliminated dehydration (48%), or that it sustained the child (15%). On the other hand, some mothers indicated that it was not efficient because it did not do any good (6%), it did not stop the diarrhoea (5%), that it produced swelling (2%), or that all it did was rehydrate the child (2%).

When they did not have access to rehydration salts, 70% used substitutes. Of these, 81% used rice water (rice cooked in water, then strained and sweetened); 68% used lemon with sugar; 21% used home remedies (described by the mothers as a liter of water boiled together with sugar and salt) and 9% used fruit drinks.

As part of the analysis of the results, each mother was assigned a total of points rating them on a scale of "traditionalism" depending on their preference for "modern" treatments such as antibiotics, anti-parasite medication and ORT, or "traditional" treatments such as herbs, baths, fruit drinks and laxatives. They were also assigned a score according to the type of help they sought when their child became ill: "modern" when they mentioned the doctor and "traditional" when the treatment was applied by a traditional midwife or healer; by the mother herself; or by the person who had supposedly caused the condition. No correlation was found between the age and formal education, and the level of "traditionalism" of the women. Nevertheless, mothers with a higher level of schooling were those who had more favorable attitudes towards the use of ORT.

The Epidemiological Study

There were 3175 people living in the 500 homes that were interviewed (6.4 persons per family), of whom 799 were women over the age of 14. Of these, 391 had one or more children under the age of five years. In total, 599 children under five years of age were recorded in the 500 houses, 216 of whom had diarrhoea during the two weeks prior to the survey.

Table 1 represents the number of cases of diarrhoea which occurred during those 14 days and the health resources and remedies sought by mothers. The cases of diarrhoea are distributed according to the ten types previously described, plus "pujo" and "hot stomach", which were identified on completion of the ethnographic study.

"Pujo" was described as watery, green diarrhoea, occasionally with mucus. The child suffering from pujo has to exert much pressure in order to defecate. "Their ribs become

Table 1. Types of diarrhoea suffered by 216 children under the age of five, during the 14 days prior to the survey, and resources of health services and treatment sought by mothers. Epidemiological survey, municipality of Villa Carlos Fonseca, Nicaragua, 1990.

Type of diarrhoea	No. of cases	% of the total	Sources of treatment sought by the mother					Treatment used			
			Help*	Doctor	Healer	ORT	Antibiotics	Parasite Medication	Laxatives	Medicinal Plants	
Parasites	45	21	21	18	3	1	4	20	1	6	
Infection	36	17	17	17	...	6	18	4	1	3	
Bad stomach	25	11	5	5	...	7	6	3	3	1	
Empacho	18	8	5	3	2	4	7	2	2	...	
Pujo	16	7	5	4	1	1	2	3	1	5	
Hot stomach	12	5	4	3	1	2	1	1	1	2	
Movimiento	11	5	5	5	...	1	3	2	...	1	
Worms	10	5	1	1	...	4	1	1	2	1	
Dysentery	7	3	5	4	1	3	1	2	...	2	
Fallen fontanelle	2	1	2	1	1	...	1	...	1	...	
Sol de vista	2	1	1	...	1	...	2	...	...	...	
Sol de cielo	2	1	...	...	...	...	...	...	...	2	
Other †	5	3	3	3	...	2	1	...	...	1	
Did not know	25	12	7	6	1	5	...	4	1	2	
Total	216	100	81	70	11	36	47	42	13	26	

* The mother sought help from health center or a traditional midwife or healer.

† Diarrhoeas caused by measles or which children had at birth.

ORT = oral rehydration therapy.

hot", but there is no fever. "Hot stomach", on the other hand, is a green or yellow diarrhoea, without mucus, and with only the stomach area becoming hot. It is believed that both diarrhoeas are caused by heat: high temperatures; "a strong gaze"; or lack of cooling drinks. They can be cured with cool drinks and baths.

As indicated in table 1, in 81 cases (37%) of the 216 children who had diarrhoea, mothers sought help; 70 (32%) visited the health center and 11 (5%) consulted the traditional midwife or healer. Only 36 (17%) of mothers applied ORT. The use of ORT was directly related to the source of help sought by mothers. For example, 36% of mothers who visited the health center used ORT, while only 8% of those who did not seek help used it. None of the mothers who visited the traditional midwife or healer used ORT. With regard to other treatments, it must be mentioned that antibiotics and anti-parasite medication were used in a higher proportion than medicinal plants and laxatives.

The diarrhoeas considered by mothers to be potentially fatal in the ethnographic study were divided into two groups: one which included "traditional" diarrhoeas and the other "modern" diarrhoeas. "Traditional" diarrhoeas included empacho, sol de vista, fallen fontanelle whose causes according to the mothers were not similar to those of western medicine. Those that did have similarities to western medicine were classified as "modern", such as worms, parasites, infection and dysentery.

Table 2 shows the response of mothers to "modern" or "traditional" diarrhoeas, considered to be dangerous. It concerns a sample of 120 children from the total group of 216 children under the age of five. A relationship can be distinguished between the mother's diagnosis and her response to the diarrhoea. In the case of "traditional" diarrhoeas the administration of laxatives and visits to the traditional midwife or healer were more common. However, also in some cases, modern treatments were sought (doctor, ORT).

Table 3 records the responses of the mothers according to the diarrhoea most frequently suffered by their children of different ages and to the question of whether or not their children under five years had ever had that type of diarrhoea. As can be observed, the epidemiology of the types of diarrhoea was different according to ages. During the first year of life, "traditional" diarrhoeas were the most important. It can also be noted that dysentery was the less frequent (13%) type of diarrhoea while infection the most frequent (67%). More than a quarter of the mothers indicated that one or more of their children had suffered from at least one of the "traditional diarrhoeas".

The 799 women over the age of 14 who were surveyed also informed the investigators of children who had died and the cause of death. In this group, 3516 children had been born and 451 had died, 143 from diarrhoea (32%). Table 4 indicates the type of diarrhoea suffered by the child upon death, according to the mother's diagnosis. Three types of diarrhoea - empacho, sol de vista and fallen fontanelle - caused 26% of the deaths. As indicated in table 2, only 18% of the mothers take their children in this state to the doctor.

Table 2. Percentage of cases and types of diarrhoea according to health resources and treatments sought by mothers of 120 children under five and their perception of the diarrhoea as "modern" or "traditional". Epidemiological survey, municipality of Villa Carlos Fonseca, Nicaragua, 1990.

Health resource sought	Modern		Traditional Empacho, Sol de Vista Fallen Fontanelle
	Parasites Worms	Infection Dysentery	
Did not seek help	60	49	64
Visited a doctor	35	49	18
Visited a traditional midwife or healer	5	2	18
Used ORT (total)	9	21	18
Visited a doctor and used ORT	5	29	50
Did not visit a doctor, but used ORT	11	14	11
Used antibiotics	9	44	46
Used parasite medication	38	14	9
Used laxatives	5	2	14
Used medicinal plants	13	12	0

ORT = oral rehydration therapy

Table 3. Frequency percentage of different types of diarrhoeas according to the age of the child among children of the 391 mothers who were interviewed, according to the responses to questions indicated below. Epidemiological survey, municipality of Villa Carlos Fonseca, Nicaragua, 1990.

Type of diarrhoea	Age			Sometimes*
	0-12 months*	1-5 years †	0-5 years	
Parasites	9	40	24	62
Infection	26	11	19	67
Bad stomach	4	12	8	47
Empacho	13	2	8	38
Pujo	9	4	6	52
Hot stomach	10	6	8	51
Movimiento	11	3	7	61
Worms	4	21	13	59
Dysentery	3	5	2	13
Fallen Fontanelle	3	0.25	1	25
Sol de vista	4	0.25	2	32
Sol de cielo	3	0.25	2	30

* What type of diarrhoea was most frequent in your children between the ages of 0 and 12 months?

† What type of diarrhoea was most frequent in your children between the ages of 1 and 5 years?

• Had one or more of your children under five years of age this type of diarrhoea at any time?

A relationship, though not statistically significant, was discovered between age and schooling of the mothers and the type of help sought by them. Mothers who took their children to traditional midwives or healers were older (on average 30.3 years) and had less formal schooling (2.8 years on average) than those who took their children to the

health center (on average 27.4 years with 4.1 years of schooling). Mothers who did not seek help were on average 28.5 years of age with 3.3 years of schooling.

Table 4. Number and percentage of 143 children under the age of five who died from different types of diarrhoea, according to the mother's diagnosis and a comparison with its incidence. Epidemiological survey, municipality of Villa Carlos Fonseca, Nicaragua, 1990.

Cause of death	No. of deaths	%	Incidence*
Infection	30	21	17
Empacho	27	19	8
Dysentery	16	11	3
Worms	9	6	5
Sol de vista	6	4	1
Fallen fontanelle	4	3	1
Parasites	3	2	21
Pujo	1	1	7
Bad stomach	1	1	11
Did not know	46	32	12
Total	143	100	-

*Based on Table 1.

Discussion

The typology of diarrhoea that emerges from both studies is similar to those described in other research carried out in Nicaragua^{31,33} and to those that have been elaborated for other Central American countries^{5,31,34} and other Latin-American cultures outside the isthmus^{35,36}. Empacho in Nicaragua is similar to what is also called empacho in Honduras, Guatemala, Mexico, Peru, Chile and among Puerto Ricans in the United States^{5,15,31,35-38}, and "pega" in Costa Rica³⁹. It is also somewhat similar to what is called "infection" in Ecuador⁴⁰.

The classification of "cold" or "hot" is the central organizing principal underlying popular etiology of diseases within Latin American countries^{41,42}. In Nicaragua, this classification explains the origins of diseases such as "sol de vista", and "hot stomach". Furthermore, it characterizes food and beverages, and indicates whether it is convenient or not to consume them. Nevertheless, it is a system that is not used in a generalized or coherent manner and can be compared to the case of Mexico, where the classification of "cold" and "hot" remains, but only in a very rudimentary way^{33,43}.

It is interesting to observe that the frequency with which the different diarrhoeas occurred in the 216 children, during the two weeks prior to the survey (see table 1), coincided considerably with those noticed by mothers in their children between the ages of 0 and 5 years of age (see table 3). This reveals a consistent popular nosology and a clear epidemiological pattern of the different types of diarrhoea.

The epidemiology of the different types of diarrhoea appeared to be different depending on the age of the children. The "traditional" diarrhoeas played a significant role during the first year of life, when mortality resulting from diarrhoea is at its highest. Of infant deaths 26% were attributed to "empacho", "sol de vista" and fallen fontanelle, which is a very high number if the rate of frequency of occurrence is taken into consideration. This is especially true for "empacho" (see tables 1 and 4). Diarrhoeas identified with these names presented the following inconveniences: mothers were less likely to visit a doctor, and more likely to visit a "traditional midwife or healer", and more likely to use laxatives, increasing the risk of dehydration. This practice was motivated by the belief of many mothers that "doctors do not know about such diarrhoeas as 'empacho' and do not know how to cure them". Dysentery also claimed many victims if its low incidence is taken into consideration, although the majority of mothers did visit a doctor when they recognized it as such.

In both studies, the mother's diagnosis was very important in deciding what type of help to seek and what kind of treatment was required in each case of diarrhoea. This result has also been obtained in other studies carried out in other socio-cultural contexts, such as Zimbabwe⁷, Pakistan^{9,12}, Bangladesh¹⁰, South Africa¹¹, Sri Lanka¹³, India¹⁴ and Guatemala¹⁵. In many studies it has been proposed that the popular taxonomy of diarrhoeas, as well as mothers' traditional responses to them, be taken into account when designing programmes to promote ORT⁷⁻¹⁴. Also in other studies it is suggested that "traditional midwives or healers" be incorporated into these programmes^{11,12}. Furthermore, it is recommended that health personnel's awareness of traditional beliefs be increased in order to improve communication with mothers. It is thought that if the personnel understood popular beliefs and used the popular taxonomy for diarrhoeas, it would facilitate access of members of traditional cultures to health services^{7,9}.

In the ethnographic study, no relationship was established between the level of formal education and the age of mothers and their "traditionalism", but it was noted that mothers with more years of schooling had a more accepting attitude toward the use of ORT. In the second study, it was determined that the mothers who had received more schooling visited health centres more often.

As can be observed in table 2, mothers used "traditional" treatment (such as medicinal plants) for "modern" diarrhoeas, and also "modern" treatments for "traditional" diarrhoeas. It can thus be inferred from this information that, although mothers will not change the traditional taxonomy for diarrhoea, their attitude towards treatment could change. This is why they were combining "traditional" and "modern" treatments, similar to what was described in an ethnographic study carried out in Papua New Guinea⁴. This is also the case in Hispanic communities of the United States where popular taxonomy, similar to that of Nicaragua^{38,44,45}, is still used for diarrhoeas even though mothers take their children to doctors.

Health personnel often scorn many practices that are part of "traditional" treatment, considering them to be a danger to health. For example, it is believed that laxatives increase

dehydration, without taking into account the fact that usually only a very small doses is given to children. It is also thought that wrapping a child with fever in a sweaty cloth could provoke febrile convulsions, without considering the fact that this procedure is often combined with an alcohol or herb bath.

In 1990 the use of ORT was still infrequent and was not generalized in rural Nicaragua. Its use by 17% of the mothers in our study coincided exactly with the 17% registered in a study carried out in Honduras, where traditional medicine is similar to that of Nicaragua⁴⁶.

The ethnographic study showed that giving rice water to children with diarrhoea a common practice was. It is worth mentioning that if part of the sugar were replaced by salt in the rice water, it would become an adequate means of oral rehydration.

Conclusions

The studies described here confirm that traditional beliefs and practices continue to exist in the rural areas of Nicaragua and have a direct influence on the manner in which mothers respond to diarrhoea in their children. Furthermore, they limit the use of health services and ORT.

On the other hand, although mothers maintain the traditional taxonomy for diarrhoea, it is also true that their behavior can be changed regarding its treatment. It has been observed that "traditional" and "modern" treatments are, at times, combined.

It would be interesting to carry out research on traditional treatments and measure their effects. Empirical data should be obtained on practices such as the use of laxatives and massages applied when the case is believed to be "empacho" and the wrapping of children in a sweaty shirt when "sol de vista" is suspected, in order to evaluate the merits of each treatment and stimulate their adaptation or replacement. In this sense, promoting rice water with salt could be appropriate for replacing commercial oral rehydration salts.

The use of ORT was not very frequent in the population studies, but it was evident that its use increased when mothers visited the health center. In order for health services to receive all types of diarrhoea, including "traditional" diarrhoea, there must be better communication between mothers and health personnel. Therefore, it is essential that this personnel be trained in the knowledge of traditional medicine. This would permit understanding of traditional beliefs and practices and the use of popular names for the different types of diarrhoea during medical visits. It would also lead to an increase in the understanding between mothers and health personnel, and, possibly the acceptance by mothers of the recommended "modern" treatment or adaptation of traditional medicine (such as rice water with salt), and of the fact that health services are valuable resources in the treatment of any type of diarrhoea.

Traditional medicine can and should play an important role in designing programmes for the prevention of diarrhoea. The results of the two studies described here can form a solid basis for planning and performing such programmes, as was done previously in the case of promoting hygiene in Villa Carlos Fonseca. A promotional programme must recognize the importance of popular knowledge, respect it and use it as a guide in the modification of potentially harmful practices. It is also important to recognize other difficulties, such as the lack of water, which at times creates an obstacle to these changes.

In Nicaragua, popular knowledge is a result of both traditional and modern medicine. A good programme must take into account this plurality and seek the means for explaining the causes of diarrhoea, combining traditional and modern concepts. Mothers will feel motivated to change their habits only if they understand the relationship between harmful hygienic practices and their children's diarrhoea. Infant mortality caused by diarrhoea could be reduced considerably in Nicaragua and other countries with similar societies and cultures if popular knowledge of diarrhoea were recognized, if communication between mothers and health personnel were improved and if programmes were designed to prevent diarrhoea and promote ORT in accordance with local cultures.

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Chapter 5

Well water study, part 2

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A Consultancy Undertaken for COWATER International INC
Liverpool Associates in Tropical Health
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Summary

While the theory of water contamination is well developed, there is a general lack of empirical support for the effectiveness of the numerous potential interventions to improve microbiological water quality. The few published studies which are available suggest that upgrading wells through improvements such as a windlass, bucket cage, drainage system, lining, head wall and cover are effective when they are provided as a combination. It is not known, however, how effective individual components of the upgrading are in reducing contamination nor whether their combined effect is greater or smaller than the sum of the separate effects. The provision of pumps seems to be useful in settings with gross contamination, and tube wells are consistently cleaner than hand-dug wells. There is also a need for a rigorous assessment of the potential impact of 'soft-ware' interventions, such as health education, on well water quality.

A literature review to identify which interventions are most likely to reduce faecal contamination of wells, waterholes and surface water

2.1. The Mechanism of Faecal Contamination of Water Sources

Fresh water is essentially distributed between three different compartments - rain, surface water and groundwater. Rainwater is normally free from faecal contamination, at least until it is collected¹. Surface water on the other hand is typically highly contaminated in developing countries. The faecal contamination of surface water implies that at some stage in the water cycle faecal matter is mixed with rainwater. Groundwater, like rainwater, is also usually free from faecal contamination. The relative purity of groundwater compared with surface water is due to (a) the death of microbiological contaminants and (b) the filtering effect of soil^{2,3}.

Coliform bacteria have a half life of about 17 hours⁴ and bacterial half-lives in wells and laboratory groundwater are mainly in the range of 8 - 24 hours³. This implies that without replenishment, FC contamination of water sources will decrease by a factor of 100 in less than 11 days. However, this process is highly dependent on temperature, and survival is therefore possibly lower in warm climates. On the other hand, as has already been pointed out, the survival of different pathogens varies greatly (table 1 of Well Water Study part 1).

Soil filters bacteria best when the particles are fine (<1mm), when the unsaturated zone in the water table lies at more than 2m below the surface, and when groundwater flow velocities are low. Faecal bacteria in soil are also eliminated by antagonistic aerobes and anaerobes³. The risk of groundwater contamination is therefore greatest where the water table is shallow and where fissured non-porous bedrock is overlaid by shallow soils. Lateral migration of faecal bacteria generally does not exceed the 10m. Older latrines pollute less, because of pore clogging of the walls. In general the distance between a water supply and an on-site sanitation unit for safe lateral separation should be 15m. It depends however, on the aforementioned factors and in some areas 5m is probably sufficient.

From a public health point of view, groundwater contamination in developing countries is of much less significance than surface water contamination. The level of contamination of rivers, streams, canals, pond depends primarily on:

1. The degree of environmental surface contamination which itself is determined by a multitude of factors such as population density, the number of people using the source, the way people fetch the water, sources of pollution around water supply (eg animals), bathing and defecation practices, ambient temperature, humidity, rainfall and wind.

2. The amount of water in which the pollution becomes diluted. This in turn will depend on the exact amount of water present at the moment of pollution and the turnover of the water. The more water is extracted or streaming away and the more water there is, the more dilution of contamination is taken place.

For scoop holes, waterholes and hand-dug wells the level of contamination is a function of groundwater quality, the rate of introduction of faecal contaminants, the rate of water extraction, the volume of water in the well, and the survival of the microorganisms.

2.2. Determinants of the Level of Faecal Contamination

2.2.1. Water source

There are many different studies which have documented water quality^{5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24}. The highest levels of faecal contamination of drinking water sources are usually found in rivers where they range from less than 10 FCs per 100ml up to 2 million FCs per 100 ml. Ponds and canals can be equally contaminated while streams tend to be a little less contaminated.

Springs, waterholes and hand-dug wells have lower levels of faecal contamination with values typically ranging from 0 to 10,000 FC/100ml. In some cases however, levels as high as one million FCs per 100ml can be found. The variation in contamination of these sources is enormous. Springs are usually less contaminated than waterholes and hand-dug wells. As stated earlier, rainwater is inherently clean but can readily be contaminated depending on the way it is collected^{1,21}.

2.2.2. Season

The marked seasonal variation in water quality is well known^{25,26} and is closely related to rainfall^{16,27}. It tends to affect surface water and unprotected well water more than water from protected wells and boreholes²⁴. There are two factors giving rise to the seasonal variation in water source contamination. One is the run-off effect whereby rain washes faecal matter into water sources. The other is the concentration/dilution effect in which dry weather reduces the volume of water and hence concentrates the existing level of contamination. Support for the importance of this effect was provided by Wright²⁰, who in Sierra Leone noted increasing levels of faecal contamination during the dry season.

Blum¹⁵ in Nigeria found that contamination peaked during transition from the dry to the wet season when the mean FC counts for all sources except rivers were 2.5 to 7.2 times greater than during the rest of the year. The lowest FC counts occurred at the height of the wet season. A similar pattern has been observed in Costa Rica²⁸, Papua New Guinea²⁹, the Gambia³⁰ and Nicaragua³¹. Blum's explanation takes both the run-off effect and concentration effect into account. The first rains wash the faecal matter into the water source, progressing the wet season there develops a rain induced dilution. At the onset of the dry season, bodies of water again begin to shrink and counts rise¹⁵. That there are still considerably higher levels of contamination during the wet season than during the

dry season is because the water levels of the wells during rain rise, but not enough to counter the increased rate of pollution due to run-off¹⁶.

2.2.3. Other factors

Most of the microbiological pollution of water sources is due to the external introduction of contaminants through either poor design or unhygienic methods of water extraction. Interventions to reduce this cause of pollution are discussed below. There are several additional factors however, which relate to water contamination.

One of these is the number of households using the source. In a Kenyan study, 70% of the wells that were used by only one family, had FC counts below 100 per 100ml, compared with 15% when one to five families used the well²³. In the latter case, each family used its own bucket and rope which were frequently placed on the ground. In Nicaragua we found a relation between the quality of the water and the number of households using the well, the amount of water extracted daily and the distance of the well from the nearest kitchen³¹.

A marked variation between countries in the contamination levels of water sources can be observed from the literature. Low contamination was found in a study from Zambia²² where none of the shallow wells had over 50 FCs per 100ml. In Sri Lanka²⁵ the geometric mean FC count for protected hand-dug wells was also low (93/100ml). Higher levels were seen in a study in Kenya where 68% of hand-dug wells and 19% of springs had more than 100 FCs per 100ml²³. In Gambia contamination of hand-dug wells was around 20,000 FCs per 100ml during the dry season and up to 500,000 FCs per 100ml during the wet season³⁰. While there are many possible explanations for this variation, population density is one factor, which may be important. In Nicaragua, there was a significantly lower level of FC contamination in rivers, streams, unprotected wells, springs, and protected wells for small communities compared with large communities²⁴. Also in between years differences in FC contamination can be found, probably due to variations in climate. In 1986 we found in protected hand-dug wells a geometric mean FC counts of over 1,000 FCs per 100ml²⁴, meanwhile in 1991 this was not more than 300 FCs per 100ml³¹, although in both studies the sample sizes were small (15 wells).

2.3. Interventions to Reduce or Prevent Faecal Contamination of Water Sources

In our discussion of the various interventions, which can reduce or prevent faecal contamination of water sources, only those involving relatively simple and inexpensive constructions have been considered.

2.3.1. Interventions to Reduce Surface Water Contamination

Rivers, streams, canals and ponds are often heavily contaminated by run-off and defecation by animals and people in and around the water. Often people attempt to protect themselves from the effects of river and stream water contamination by taking their

drinking water upstream of their village or by digging holes alongside the river, and sometimes even protected by a parapet. Water seeps into the hole and in doing so it is filtered by the soil. In Nicaragua it was observed that people completely empty the water from these little wells and allow them to refill each time they collect water²⁴. Interestingly, during dry periods the quality of water in these unprotected wells was significantly higher than in domestic wells protected with a lining and parapet and often less than 1% of the level in the adjacent river.

Another possibility is filtering the water within the source, for example Jempeng stone filter used in canals in Indonesia or sand-filtering wells developed in China³². Filtering the water in the home is also an option. For example, there is winnowing sieve, the cloth filter, clay vessels, plant material, and the family sand filter^{27,32}. It is claimed that these sorts of filters yield water of a very high microbiological quality (presumably FC counts of less than 50 per 100ml) although no data have been found to verify this. Another option is solar disinfection as described in the earlier mentioned study in the Lancet³³.

Spring water, which is often relatively clean anyway, can be improved by constructing a spring box consisting of a headwall, outlet pipe and backfill cover^{23,34}. One study³⁴ found that only 20% of protected springs tested positive for *E. coli* compared with 62% of unprotected springs. Rain jars with mosquito nets placed on the roofs of houses are a safe way of collecting rainwater with mean FC counts of less than 10 per 100ml.¹

2.3.2. Interventions to Reduce Well and Waterhole Contamination

Four basic strategies can be used to reduce well and waterhole contamination. These are (a) diluting the pollutants, (b) preventing groundwater contamination, (c) preventing surface contamination and (d) treating the water³⁵.

2.3.2. (a) Diluting the pollutants

Blum¹⁵ in Nigeria found that contamination peaked during transition from the dry to the wet season. But the lowest FC counts occurred at the height of the wet season. This is presumably because of a dilution effect. One option for improving water quality would therefore be to increase the depth of water in the well or by widening the well.

However, another way to dilute the contaminants is to increase water turnover. Presumably this is why riverside waterholes may have better water quality than large, protected, hand-dug wells²⁴. It may also partly explain why pumps on hand-dug wells are associated with better water quality²⁴. Pumps generally increase the amount of water used and hence increase turnover. Morgan²⁷ has demonstrated that this 'flushing effect' could be very significant in an experiment with a Bucket Pump installed on a tubewell. At normal rates of extraction, the total content of the tubewell is completely replaced within ten minutes. Since turnover is greater with smaller volumes of water in the well, this flushing effect will be less if the amount of water in the well is increased as suggested above. The impact of pumps on water quality in the Zimbabwe study is illustrated in table 1. In Nicaragua where electric or wind pumps are installed on traditional hand-dug wells, the geometric mean FC count was only 22 per 100ml compared with 1,410 for

wells without pumps. Expressed in another way, 90% of wells without pumps had over 50 FCs per 100ml compared with 33% of those with electric or wind driven pumps²⁴, and 55% of traditional wells with hand pumps³⁶. Another study in Nicaragua found that 26% and 23% of wells fitted with Dempster pumps and rope-pumps respectively had FC counts over 50/100ml³⁷.

Table 1. Bacteriological quality of water that is taken from wells and hand pumps

Source	Mean E. coli/100ml	No. samples
Poorly protected well	266.42	233
Upgraded wells	65.94	234
Bucket Pump (overall)	33.72	338
Blair Pump (tubewells)	26.09	248
Bush Pump (tubewells)	6.27	281

Source: Morgan, 1990²⁷

2.3.2. (b) Preventing groundwater contamination.

Groundwater pollution is usually a minor source of contamination in most wells and therefore interventions to prevent it are unlikely to have a major impact on faecal coliform counts. A study in Nigeria for example¹⁸ in which 20 wells were studied, found no correlation between water quality and the distance between the well and the latrine, nor with the depth of the water table. This result is supported by another study in Sri Lanka's Kandy District where no relationship was found between the level of contamination and the distance of the latrine from the well. Tracer tests to investigate if surface water might enter the hand-dug wells were negative, perhaps due to the nearly ideal soil material in the unsaturated zone³⁸. In Sri Lanka²⁵ 95% of the protected open hand-dug wells were contaminated. Only 5% of deep tubewells with hand pumps were contaminated when the mouth of the tap was sterilised, in contrast to 52% when it was not. Mertens *et al* concluded that groundwater contamination was negligible, the contamination occurred at the periphery of the system. However, in cases where groundwater pollution is suspected to be significant, all nearby latrines and cesspits should be removed to a safe distance (15 to 30 metres) and the lining of the well upgraded, replaced or installed as necessary.

2.3.2. (c) Preventing surface contamination.

Several design features of the protected well are intended to reduce contaminants from the surface that enter the well. A head wall/parapet with a cover will prevent faecal material, dirt and debris from falling into the well and helps to keep animals and people away from the well water. A concrete apron around the base with a sanitary seal to the head wall and lining, a drainage channel and sump at some distance from the well will prevent spilt water and rainwater run-off seeping into the well. It also keeps the area dry, which reduces breeding of bacteria, which grow better in a moist environment. Improvements in the water-lifting device, such as a windlass or hand pump will decrease or eliminate contamination of the water via the bucket and rope. A study of the faecal contamination

of upgraded wells compared with unimproved wells showed that the latter had over four times the concentration of faecal *E. coli* (Table 1), and over five times the concentration of faecal *Streptococci*. In this case the upgrading was extensive and consisted of installing a windlass, well cover, drainage apron and lining²⁷. Another study in Zambia³⁹ found significantly better water quality in upgraded wells, but drilling the wells produced even better results (figure 1). Hand-dug wells were upgraded with a lining, concrete cap, drainage channel and a windlass. A special cage around the bucket was developed to protect the bucket against stealing. Some wells were hand augured and a bucket pump was installed. Water quality was then compared between traditional wells, improved hand-dug wells some with a bucket cage and some without, improved hand-dug wells with a bucket cage and augured wells with a bucket pump.

Proportion of samples

Source: Lacey (1990)

Figure 1. Relationship between water quality and well type.

When a rope and bucket are used the cover should be designed in a way that prevents water from spilling back into the well. This means the cover should have a raised collar around the extraction port. However, a study in Kenya²³ found that the presence of a cover and well lining had no effect on water quality. Similarly, the study in Nigeria¹⁸ did not detect any difference in water quality between the wells with a cover and those without. Likewise, a study in Indonesia found no improvement in faecal contamination when

hand-dug wells were upgraded by fitting a hand pump and a sanitary cover. Among the improved wells with hand pumps, 20% had contamination levels over 100 FCs per 100ml compared with 22% in the unimproved open dug wells²¹. Other studies however, have shown that a cover plate can make some difference. In a study from Cape Verde, 53% and 23% respectively of traditional hand-dug wells without and with cover plates contained *E. coli*. For coliforms the proportions were respectively 100% and 80%³⁴.

Our study³¹ of the impact of installing rope-pumps on hand-dug wells found a reduction of 62% of the geometric mean of FC compared to hand-dug wells equipped with a rope and a bucket, but no difference when compared with hand-dug wells equipped with a windlass. No difference was detected for the installation of a concrete cover plate.

Surface contamination is considerably reduced when wells are augured as the first few meters of the well are then protected by the casing which always goes with a drilled well. In addition, the opening of the well will be smaller and therefore easier to protect. The lifting device will also tend to be more hygienic. In the aforementioned Indonesian study, only 7% and 9% respectively of the shallow and deep drilled tubewells with hand pumps had more than 100 FCs per 100ml compared with 20% for among upgraded hand-dug wells and 22% among the unimproved hand-dug wells²¹.

2.3.2. (d) Treating the water.

Another way to reduce faecal contamination is by chlorination. This is normally done by periodic disinfection of the well but several methods of gradual chlorine infusion have also been experimented with. Table 2 illustrates the improvement in water quality of 4 different levels of chlorination of highly polluted open shallow wells and its effect on diarrhoeal disease. However, there are problems with chlorination such as the often unacceptable taste, the difficulty in determining and maintaining an appropriate dosage schedule, and the problems of guaranteeing a regular supply of chlorine.

Table 2. Influence of residual chlorine on water quality and on incidence rates of diarrhoeal diseases

		Control	I	II	III	IV
Residual chlorine		0	0.5	0.4	0.3	0.2
Average MPN count*	Before	820	953	1089	1100	880
	After	727	17	41	49	82
Diarrhoea incidence rate	Before	19.0	20.0	22.2	20.3	10.7
	After	29.5	1.1	1.7	2.1	3.0

*MPN=most probable number of bacteria present per 100 ml

Source: Trivedi *et al*, 1971⁴⁰

2.3.3. "Software" Interventions to Reduce Faecal Contamination

Certain behaviours may increase or decrease the level of contamination of a well. For example, placing the bucket and rope on the ground, defecating in the area near the well or allowing animals to do so, bathing or washing dishes/clothes close to the well may introduce surface contaminants. It is also conceivable that hand washing might prevent well water pollution by reducing the contact of bacteria with the rope or bucket. Hence, health education directed at modifying potentially harmful practices and promoting beneficial behaviours in addition to explaining how contaminants are introduced into wells, should in theory, give rise to water quality improvements. Health education may be particularly effective where there is private ownership of wells. However, no studies have been identified which demonstrate whether health education can lead to improved water quality and if it can, by how much.

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Chapter 6

A randomized trial of the impact of rope pumps on water quality

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Abstract

Rope-pumps are now widely promoted as a low cost, easily maintained means to improve water availability in developing countries. However, in some instances their acceptance has been limited by concerns over the microbiological quality of the water. This study looked at the well water quality under a variety of different conditions, comparing unimproved bucket and rope wells, with wells with a windlass and rope-pump wells with and without a concrete cover. Other factors influencing the water quality were also examined.

Results indicate a 62% reduction of the geometric mean of the faecal coliform contamination of the well water as a result of the installation of a rope-pump with or without a concrete cover on wells which were originally equipped with a rope and bucket. Other factors found to influence the level of contamination of water in hand-dug wells were rainfall, number of households using the well, amount of water extracted daily and the distance of the well to the nearest kitchen. The last three factors probably reflect domestic activities with poor hygiene around the well.

The installation of a simple rope-pump on family wells improves the water quality and availability at a favorable cost/benefit ratio.

Introduction

The use of inadequate water supplies relates closely to the high incidence of childhood diarrhoea in most developing countries. Both quality and quantity of water used are believed to play a role. There is a reasonable consensus that interventions which increase water availability have a greater impact than those which improve the quality of water, but combined interventions have been associated with the greatest reduction in disease (Esrey *et al.* 1991).

From the small amount of relevant literature available, it would appear that reduction of faecal contamination from very high levels to moderate levels is more likely to have a positive health impact than reductions from moderate to low levels (Moe *et al.* 1991; Sutomo 1987; Trivedi *et al.* 1971). Reductions of faecal contamination from very high levels are likely to be more effective where many families share a water source, than where the water source is used by just one or two households.

In rural Nicaragua the preferred type of water supply is the family hand-dug well (Gorter *et al.* 1991). Sharing of a hand-dug well mostly occurs between families who are relatives or in cases where the economical and/or geological factors have made it impossible to dig more wells. In the rural municipality of Villa Carlos Fonseca, more than half of the population is served by these private wells which are almost entirely equipped with a bucket and rope or a windlass. An earlier study (Sandiford *et al.* 1989) showed that these wells have high levels of contamination which rise after the rains, though not as much as other traditional water sources.

Improvements in water quality and availability for this type of rural populations can only be made at a favorable cost/benefit ratio only by upgrading the private wells and improving the method of water extraction. The few published studies of the effectiveness of the numerous potential interventions to improve microbiological water quality of hand-dug wells suggest that upgrading of wells through improvements such as a headwall, apron, drainage channel, lining, cover, handpump, windlass, or bucket cage are effective when provided as a combination (Buchrieser *et al.* 1989; Lacey *et al.* 1990; Morgan 1991). It is not known, however, how effective are the individual components of the upgrading in reducing contamination or whether their combined effect is greater or smaller than the sum of the separate effects. In order to design an effective cost/benefit intervention on hand-dug family wells the impact of the individual components of upgrading should be known.

In Nicaragua the rope-pump (Figure 1), based on the simple chain and washer pump (Lambert 1990), was introduced in 1983 (Sandiford *et al.* 1993). Extensive modifications have enabled rope-pumps to be produced which are easy to operate, have a high efficiency, low cost, and are easy to maintain (Alberts *et al.* 1993). More than 3,000 are installed in private and project sectors and recently the first 50 were introduced in Honduras.

Figure 1. Cross-section of a rope-pump on a well.

Material and methods

The study was carried out in Villa Carlos Fonseca, a rural municipality on the Pacific coastal plains of Nicaragua with a population of approximately 30,000. The area can be characterized as a tropical dry zone with small rivers which tend to dry up during the dry season. Thirty wells in 14 different communities were selected for the study and randomly assigned to three groups of 10 wells each: one group to be fitted with a rope-pump and concrete cover, a second group with only a rope-pump and the third group as a control group, not receiving a rope-pump until the end of the study.

To determine the baseline level of faecal contamination, two or three water samples were taken weekly from each well in the dry season and less than one month before the installation of rope-pumps and covers began. A baseline interview and observation were carried out to identify behavioral, structural and socio-economic factors which might influence faecal contamination. Days of rainfall were registered. Seven water samples were taken from each well every 3 weeks following installation for a total of 5 months.

The Oxfam Delagua portable water quality testing kit was used to measure faecal coliform counts by the membrane filtration method. The water quality laboratory of the

water and sewage Ministry prepared the cultures and trained the research assistant to prepare the kit, take the samples and perform the water quality tests. At the study midpoint the kit was taken to the national laboratory after incubating and samples were counted independently by the research assistant and the head of the laboratory. No differences in counts were found. The temperature reading of the incubator was also checked. Samples of 50 ml were taken from the wells using the existing method of water extraction. The samples were incubated within 6 hours of sampling at 44° C for 16-18 hours, on pads impregnated with lauryl sulphate broth.

Data were entered in Epi-info and analyzed using Epi-info and SPSS programs. A water quality model was fitted by analysis of covariance with the natural logarithm of the faecal coliform counts as the dependent variable. The independent variables considered were; method of water extraction, design of the well, protection and distance from a source of contamination, amount of water extracted daily, amount of water in the well, and various socio-economic factors.

Results

Description of wells and users

Table 1 lists the characteristics of the 30 wells, and those of the well users. The latrine to well distance averaged 28 meters (range 8-67 meters), which means that, for the type of soil existing in the area (ocean sediments of clay and limestone, sometimes covered by volcanic sand), no lateral contamination of the water from latrine to well is likely (Lewis *et al.* 1981). The 61 families had a total of 396 members. Almost a quarter of the heads of families is illiterate. The vast majority are farmers though some work in the nearby capital.

Figure 2 shows that the more water is needed and the greater the well distance, the more people shift from the well to the river. For drinking, cooking and washing dishes, all families used only well water. In 25% of cases well water was also used to irrigate their premises and in 26% to water the cattle.

Water quality

Table 2 shows the number and type of wells in each group. The Nicaraguan rope-pump company Bombas de Mecate SA installed 30 rope-pumps. Due to an initial misunderstanding between the research group and the company 3 wells in the intervention group with only a rope-pump received their rope-pump in error before the baseline measurements could be made and were therefore shifted to the control group. Of the rope-pump group with covers, 2 wells did not receive their rope-pump due the very low water levels in the wells after 3 years of severe drought in the study area and thus were also shifted to the control group. Eventually the control group consisted of 15 wells, as did the intervention group.

Table 1. *Characteristics of the study wells and their users*

Characteristics of the wells		
Presence of a headwall	100 %	
Upper section lined with masonry	100 %	
Equipped with a windlass	53 %	
Some sort of cover on headwall	43 %	
Cover is complete and in use	20 %	
Apron around headwall	10 %	
Drainage system	0 %	
Protection against animals	0 %	
Presence of a corral in the yard	43 %	
Cattle watered from the well	37 %	
Well has been cleaned	93 %	
Average time since well was cleaned(years)	0.5	
Average age of the wells (years)	17	(1-70)
Average depth of the wells (m)	14	(6-27)
Average water depth in the well (m)	1.1	(0.2-3.3)
Average distance to kitchen (m)	16	(0.85-70)
Average distance to corral (m)	19	(1-80)
Average daily water extraction (gallons)	134	(25-330)
Average number of families/well	2.1	(1-9)
Average number of persons/well	13.7	(3-65)
Characteristics of the users		
Average schooling heads families (years)	3.1	(0-11)
Amount of family-heads illiterate	21 %	
Average number of members/family	6.5	(2-16)
Average age children start drawing (years)	10	(6-15)
Average time to draw water (minutes)	40	(15-120)
Average distance family/well (m)	40	(0.7-170)
Average distance family/river (m)	650	(17-2000)
Average daily water use/family (gallons)	67	(10-330)
Usual drawers of water		
Women	63 %	
Men	19 %	
Children	10 %	
Children together with women or men	5 %	
Men and women together	3 %	

During a total of 283 visits 273 water samples were taken. Ten samples could not be taken because 4 wells were dry on 1-4 occasions. Of these 273 samples 15 were discarded because of an error in the culture and 4 because of well construction or cleaning activities in the week before sampling, leaving a total of 254 samples for analysis.

Figure 2. Choice of water source for bathing or washing clothes in relation to the distance to the well.

Table 2. The number and type of well in each group

Baseline Type	Baseline Wells	After modification		
		Control Wells	Only pump Wells	Pump/cover Wells
Bucket	14	4	5	5
Windlass	13	8	2	3
Rope-pump	3	3	-	-
Total	30	15	7	8

Table 3. Effect of rain on the geometric mean of faecal coliform contamination of the 15 control wells

	GM FC/100ml	N
Dry season (February-mid May)	189	48
First rains (mid May-end July)	268	42
After first rains (end July-September)	221	32

Rainfall commenced shortly after intervention and just one sample was taken in the dry period after intervention. Table 3 shows the effect of the rainfall on the level of contamination of the control group.

Table 4. Geometric means of faecal coliform contamination for different methods of extraction during the baseline measurements and the entire study

Method	Baseline study		Entire study		
	Crude FC/100ml	n	Crude FC/100ml	Adjusted ¹ FC/100ml	n
Bucket	323	34	288	324	56
Windlass	165	32	215	196	79
Only rope-pump	81	7	174	169	72
Rope-pump/cover	-		131	136	47
Total		73			254

1 Adjusted for the parameters used in the water quality model; rainfall, number of families/well, distance of well/ kitchen and amount of water extracted.

Table 4 shows the geometric mean faecal coliform contamination of the different methods of extraction of the 30 wells during the baseline measurements and the entire study. The third column shows the results when adjusted for all the parameters included in the water quality model. Comparison of these values gave better results for the intervention with a rope-pump and concrete cover then for the rope-pump alone. Also it gives the impression that rope-pump wells are associated with better water quality then wells with a windlass.

However, the results of faecal contamination of the different subgroups before and after intervention as presented in Table 5 show no difference for rope-pumps with or without a concrete cover. A reduction of 62% in contamination was seen in the intervention group which was originally equipped with a rope and bucket; no reduction was seen in the group originally equipped with a windlass. Overall reduction of the faecal coliform counts of all the wells supplied with a rope-pump was 47%.

Table 5. Geometric mean faecal coliform counts before and after the intervention for the different types of baseline wells intervened and for the control group.

Type of baseline well	Before intervention		After intervention			
	Crude		Crude	Corrected for rain ¹		Change (%) (95% CI)
	FC/100ml	n	FC/100ml	FC/100ml	n	
Control group	189	35	238	189	87	0% (-28/ 40)
Bucket modified with only rope-pump	455	13	211	167	33	-63% (-78/-39)***
Bucket modified with rope-pump/cover	196	12	99	79	30	-60% (-82/-10)*
Windlass modified with only rope-pump	108	5	147	116	14	+ 7% (-66/250)
Windlass modified with rope-pump/cover	171	8	213	169	17	- 1% (-54/114)
All modified bucket wells	304	25	147	117	63	-62% (-77/-37)***
All modified windlasses	143	13	180	143	31	0% (-48/ 91)
All modified wells	235	38	158	125	94	-47% (-65/-20)**

* $P<0.05$; ** $P<0.005$; *** $P<0.0001$

1 In order to compare the counts before and after intervention, the effect of rainfall was removed. Differences between the means of the natural logarithm of FC counts in the dry period and the other two weather periods (see Table 3) were calculated and subtracted from the natural logarithm of each FC count of the corresponding weather period.

Figure 3 shows the frequency distributions, before and after intervention, of the natural logarithm of faecal coliform counts of the group originally equipped with a rope and bucket.

Figure 3. Frequency distribution of the $\log_{10}$ counts of the whole bucket group. (After intervention corrected for rain).

When assigning the faecal contamination of the bucket wells to groups of very high, moderate, and low levels of contamination, all counts at the very high level are eliminated after intervention and part of the moderate counts is reduced to the low level (Table 6).

Table 6. Proportions of very high, moderate and low readings before and after intervention in the group originally equipped with rope and bucket.

	Low level 0-100 FC/100 ml (%)	Moderate level 101-1000 FC/100 ml (%)	Very high level >1000 FC/100 ml (%)
Before	12	80	8
After	31	6	0

Other factors influencing water quality

The complete model, fitted on the water quality results of the entire study, is shown in Table 7, together with the significance level for each variable. In fitting the water quality model, each measurement of a single well is considered as an independent sample as there was almost as much water quality variation for repeated samples from the same well as there was for different samples from different wells. No interactions were seen for the main effects. No difference in results of the fitted model was seen when the wells which mistakenly received their rope-pump too early and/or the wells which did not receive the planned intervention because of the drought, were excluded.

Table 7 Parameters included in the water quality model

Variable name (and type)	Range of values
Main effects	
Method of extraction*** (categorical)	1 rope-pumps 2 windlass 3 rope/bucket
Rainfall period* (categorical)	1 dry period (February-mid May) 2 first rains (mid May-end July) 3 after first rains (end July-September)
Number of families/well* (dummy)	1=1 2>1
Covariates	
Distance well/kitchen**	continuous
Amount of water extracted*	continuous

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

Contamination of the wells increases when more families are using the well and when more water is extracted daily, although these effects are less significant than the distance of the well from the nearest kitchen (Table 8). Structural factors such as a wooden cover and its use, the age or depth of well, the presence and distance from a latrine or corral, and socioeconomic factors such as schooling, type of waterdrawer and possessions of user families had no effect on water contamination. The effect of an apron, a good drainage system and protection against animals could not be assessed because none or almost none of the study wells possessed one. Neither could the effect of cleaning the well be determined, since the vast majority had cleaned their well within the last half year.

Table 8. Impact of the distance of the well to the nearest kitchen on the level of water contamination of the well

Distance well/kitchen (varas)	Crude	Adjusted*	n
	GM FC/100ml	GM FC/100ml	
1 - 9	251	260	77
10 - 19	201	200	87
20 - 29	177	176	26
>30	150	143	64
Total			254

1 Vara = 0.8359 meter

* Adjusted for the parameters used in the water quality model; method of extraction, rainfall, number of families/well and amount of water extracted.

Discussion

Results of this study indicate that faecal coliform counts are reduced by an average of 62% when a rope-pump is installed in place of a bucket and rope. A concrete cover appeared to effect no additional improvement, but the concrete covers in this study were of a poor design and did not seal the headwall hermetically. A better design is needed and its impact should be investigated.

The effect of a simple windlass seemed almost as great as that of a rope-pump, although pre and post-installation measurements were not made. The effect of a rope-pump or windlass must be ascribed to the elimination or reduction of contamination of the rope and bucket being dragged on the ground and touched by the hands. Improvement of water quality by installing a windlass and upgrading the well with a cover, drainage apron and lining has been reported in other studies (Morgan 1991; Lacey *et al.* 1990).

Other factors found to have an impact on contamination of the wells included rainfall, number of households using the well, amount of water extracted daily and the distance of the well from the nearest kitchen. The last three factors probably reflect domestic

activities with poor hygiene around the well. The association with the number of households using the well has been described in Kenya (Nyangeri 1986). The amount of water within the well may have some influence; reflecting dilution of the faecal contamination introduced daily into the well and its subsequent die-off. The fact that contamination of wells peaks during the start of the rainy season and returns to normal levels after the first rains is consistent with studies in other regions (Barrell & Rowland 1979; Blum *et al.* 1987; Feachem 1974; Mertens *et al.* 1990b; Moore *et al.* 1965; Wright 1985).

In developing countries, only around 40% of the rural population have access to good quality of water (Huttly 1990). The other 60% use traditional water sources of generally poor quality, among which the protected hand-dug well is one of the less contaminated; only springs are usually cleaner (Feachem 1980; Lindskog & Lindskog 1988; Sandiford *et al.* 1989; Tensay 1991; Utkilen & Sutton 1989; White *et al.* 1972; Wright 1985). Geological, socioeconomic and ethnographic factors determine the type of water supply and, in the case of hand-dug wells, the density of these wells. Where water depth makes it possible, people dig their own private or communal wells and this remains the most common method of groundwater exploitation, probably even more important than drilled wells (Clark 1988). To improve water and sanitation for this rural population, hundreds of programmes have been developed to drill, dig or upgrade communal wells and to equip them with a handpump. Many programmes failed due to abandoning of wells because of frequent breakdowns of the pumps and insufficient maintenance and hygiene education. Maintenance and hygiene education have now become a central feature of these programmes (Reynolds 1992; Kerr 1990). Besides, studies of water quality have shown that hand-pumps do not always yield the expected water quality improvement (Lloyd & Suyati 1989; Mertens *et al.* 1989; Wedgwood 1989). Consequently a shift has taken place and programmes to upgrade the old-fashioned family well and equip them with an improved method of extraction have gained in popularity (McIntosh 1989; Morgan & Chimbunde 1991; Utkilen & Sutton 1989).

Such programmes could have an important impact on the incidence of diarrhoeal disease. In the first place, the amount of water used for hygiene purposes will increase as availability increases through a decrease in the distance to the water source, improvement of the method of extraction or a decrease in the number of users per water source (Cairncross & Cliff 1987; Frankel & Shouvanavirakul 1973; Hoque *et al.* 1989; Sandiford *et al.* 1990; White *et al.* 1972). Secondly, the level of contamination of the well will decrease from high to moderate and eliminate very high levels of water contamination. Finally, protected hand-dug wells are used by fewer families than most unimproved sources. Since disease transmits readily by person-to-person contact in such households, water quality is less important. Many studies of in-house contamination of stored drinking water found no relation with diarrhoeal disease (Han *et al.* 1991; Henry & Rahim 1990; Mertens *et al.* 1990; Moore 1965). The same could account for the family well, in contrast to the community well where contaminating pathogens can come from all the families using the water source and where the source could be an important transmission route. Whether a persisting low level of faecal contamination of family well water still poses a serious risk for diarrhoeal diseases remains to be investigated.

Simple cheap rope-pumps can yield a significant improvement in water quality while simultaneously increasing availability. Upgrading the well with a drainage system, a well designed cover or an extra large tube (to shift domestic activities around the wells to a point of some 10-20 meters from the well) and hygiene education programmes may further improve water quality. The low cost and easy maintenance of the rope-pump makes it appropriate for family wells.

Conclusions

Results indicate a 62% reduction in the geometric mean of the faecal coliform contamination of the well water due to the installation of a rope-pump with or without a concrete cover. Other factors found to influence the level of contamination of water in hand-dug wells were rainfall, number of households using the well, amount of water extracted daily and the distance of the well from the nearest kitchen. The last three factors probably reflect domestic activities with poor hygiene around the well.

The installation of a simple rope-pump on family wells improves the water quality and availability at a favorable cost/benefit ratio. They can be considered a viable option for rural water and sanitation programmes in developing countries and a good adjunct to the traditional family wells. Additional programmes of upgrading the wells and hygiene education may improve the water quality, but their impact remains to be investigated.

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Chapter 7

Discussion

Discussion

Worldwide, death due to diarrhoea in children under-5-years has decreased from an estimated 4.6 million in 1982¹ to 3 million in 1993², still it is the second most important cause of death in that age group. Of 11 million deaths among children under the age of 5 in the developing world, 4 million are attributable to acute lower respiratory infections, 3 million to diarrhoea and a further 1 million to measles³.

A review of the literature on diarrhoea provides no evidence of a decrease in its incidence in developing countries. The very rough estimates for the global incidence of diarrhoea have remained the same for the last 10 years: 1 billion episodes per year⁴. Diarrhoea remains a major cause of morbidity, with attack rates ranging from 5-12 per child under 5 per year to as many as 18 during the first year or two of life in the poorest areas of the developing world⁵. Each episode of diarrhoea, if it is not properly managed, contributes to malnutrition. When episodes are prolonged, their negative impact on growth is increased. In terms of incidence rates this condition dwarfs all others². Many investigations have indicated that of all childhood illnesses, only diarrhoeal disease can have a significant negative effect on growth⁶.

Prevention of the morbidity from diarrhoeal diseases will reduce malnutrition in infants, which in turn will result in a lower vulnerability to other diseases, such as respiratory infections and measles. This will not only result in fewer deaths due to diarrhoea but will also reduce deaths due to other infectious diseases. Diarrhoea contains 7% of the burden of disease in the world⁷, which makes major efforts to decrease its incidence justifiable.

In spite of many actions during the last decades, the incidence of diarrhoea in developing countries is still high. The attack rates in developed countries are currently estimated at only 1-5 per child under 5 per year, with the highest rates observed under special conditions such as in day care centres⁵. The interruption of the transmission of diarrhoeal pathogens has proven to be much more difficult than originally expected⁸.

In the developed world, with its relatively good infrastructure of water, sanitation and education, the transmission of diarrhoeal pathogens has become limited. When transmission occurs and the pathogens cause diarrhoea, the source of the pathogens and the transmission route are investigated and if necessary, measures are taken. (Examples: Cryptosporidiosis in water wells; E.Coli in the fast food chain; different types of pathogens in day care centres; Salmonella in the food chain)⁹.

Recent research has suggested that in the United States affluence and education in the last decade of the nineteenth century made little difference to child mortality, until scientific knowledge showed households how to reduce the dangers to their health¹⁰. Since individuals with more education acquire and use new information more quickly, this emphasis on knowledge helps to explain the large differences in child mortality by mothers' education observed in developing countries today. However, the presence of certain material resources such as water supplies, systems for the safe disposal of faeces, and

soap in the case of prevention of diarrhoeal disease, should be considered preconditions for a change in behaviour through health education. Without these preconditions 'good' practices simply cannot be performed consistently, although knowledge exists. In this way poverty and ill-health are closely interrelated. "While poverty prevents a person from satisfying the most basic human needs (adequate food, safe and enough water and sanitation, and access to social services such as basic health and education), ill-health inhibits an individual's ability to work, reduces earning capacity and deepens poverty".²

Table 1 gives an idea of the actual situation. In 1995 25% of the populations of developing countries still lacked safe water, 66% had no access to an adequate system for the disposing of faeces, and 38% of the women were illiterate³. Cleanliness of water is not the only issue; the importance of an adequate water supply for household hygiene cannot be over-emphasized. An unknown percentage of the population lacks an abundant water supply "on the premises". Unfortunately accurate data are not available. It can be assumed that an abundant water supply is available for fewer people than those who have access to clean water. Figures for households having safe water are the sums of combinations of households with different types of water sources, such as domiciliary connections and household wells, but also include communal hand-dug wells or communal perforated wells equipped with hand-pumps. Of these water sources an unknown, but probably much smaller number will be on the premises of these households.

Although Nicaragua belongs to the poorest 30 countries of the world¹¹, it does not fall in the group of 47 Least Developed Countries (LDCs) as defined by the World Health Organization, which uses basic indicators such as life expectancy, under-5-mortality and infant mortality³. This is also reflected by the relatively good situation of Nicaragua's water supply, sanitation and female literacy in the urban areas (table 1). The data have been collected in a nationwide population survey in 1995¹². The table also shows data that we collected in 1990 during a population survey of morbidity and mortality of a random sample of 10% of the houses in Villa Carlos Fonseca.

Table 1. Unsafe water, inadequate disposal of faeces and illiterate women.

	% unsafe water	% inadequate disposal of faeces	% illiterate women
Developing World	25%	66%	38%
Range LDCs ¹	17-92%	37-94%	29-93%
Nicaragua all	15%	32%	26%
Nicaragua urban	1%	5%	15%
Nicaragua rural	31%	44%	44%
Villa Carlos Fonseca	24%	38%	32%

¹ Least Developed Countries

An interesting aspect of the Villa Carlos Fonseca studies is that when our team started in 1986, we intended to perform only one study; one of the first case-control studies of diarrhoeal diseases in developing countries. At that time we had no idea how our research would develop over the next ten years. It became an integral programme of diarrhoeal disease research with the utilization of the results in health promotion programmes. Later components were shaped by the earlier work - e.g., the evaluation of the installation of rope-pumps was inspired by the evidence from the case-control study that lack of water availability caused more diarrhoea.

When our first water and sanitation study started, the importance of the role of the water quantity versus the water quality in the transmission of diarrhoeal diseases was still unknown. Over the course of time the evidence from our and other studies showed that the amount of water that was available to households, was more important than its quality. The role of sanitation is still discussed, but it is now generally accepted that not only the sanitary equipment but also the hygienic behaviour around the disposal of faeces is important.

Our Villa Carlos Fonseca studies showed that the quality of the drinking water was less important than the distance from the house to the water source. In spite of marked differences in water quality between the different types of water supply, no effect of water quality on diarrhoea morbidity was found. In contrast, there was a clear association between the water availability and diarrhoea morbidity. Children from homes with water supplies over 500 metres from the house had much higher rates of diarrhoea compared to children from houses with their own water supply. The presence of a latrine made no difference. A mother's level of schooling was inversely correlated with the frequency of diarrhoea in her children. A significant effect on the incidence of diarrhoea was also found for the number of children under the age of five living in the house.

In the hygiene study we detected a consistent effect of almost all hygiene practices on diarrhoea. More schooling produced a better hygiene behaviour, this being slightly stronger in the presence of a radio. Our study was one of the first to observe simultaneously these many hygiene practices, to perform the observation on more than one occasion and to relate the findings to the incidence of diarrhoea. In our hygiene study the existence of a latrine had a beneficial effect, but mothers' behaviour with regard to the disposal of children's stools was at least as important. In rural Nicaragua children under the age of 5 use a latrine infrequently because they are afraid of the 'black hole', while mothers regard their faeces as benign. Consequently, cleaning occurs more for cosmetic/aesthetic reasons than because of the mothers' knowledge of transmission routes. This normative concept of the mothers' behaviour performing 'good' practices because they are socially acceptable rather than effective in the prevention of diarrhoea, has also been described elsewhere and fits well with Fishbein and Ajzen's Theory of Reasoned Action¹³.

The ethnographic work shows the importance of local health beliefs. The studies confirm that traditional beliefs and practices continue to be important in rural areas of Nicaragua and have a direct influence on the manner in which mothers respond to diarrhoea in

their children. Traditional medicine must still play an important role in the design of programs for the prevention of diarrhoea. A promotional program should recognize the importance of popular knowledge, respect it and use it as a guide in the modification of potentially harmful practices. In Nicaragua, popular knowledge is a result of both traditional and modern medicine. A good program must take into account this plurality and seek the means for explaining the causes of diarrhoea, combining traditional and modern concepts. Mothers will feel motivated to change their habits only if they understand the influence of harmful hygienic practices on their children. Infant mortality caused by diarrhoea could be reduced considerably if popular knowledge of diarrhoea were recognized, and if programs were more designed in accordance with local cultures and health beliefs.

A complicated relationship exists between socio-economic status, education, cultural factors and hygiene practices. Most studies on hygiene show that hygiene practices improve as education (and affluence) increases, although in some studies only knowledge, and not also practice, increases²⁸. People's behaviour is not only determined by their level of knowledge of disease prevention, but also by the local culture and the available preconditions, such as water, soap and time. Even if enough knowledge exists, without these preconditions, 'good' practices simply cannot be performed consistently, while social and cultural factors may have a reinforcing or restraining influence. Personal, domestic and community/public hygiene are now considered to play a far more important role than was foreseen years ago. Recently dozens of hygiene studies have been performed, and many are still underway.

To reduce the transmission of diarrhoea, several important transmission routes must be blocked. As Briscoe argues, for diseases such as diarrhoea, where there are multiple transmission routes, reducing transmission by the dominant route will not necessarily produce a corresponding reduction in the incidence rate of that disease¹⁴. In highly contaminated environments, where multiple transmission routes are acting together, the health impact of improved water supplies or sanitation may be limited. Shuval *et al.* even claim that there is a socioeconomic threshold below which investments in water supplies and sanitation facilities alone will result in little or no health improvement¹⁵. Cairncross *et al.* reason that the control of the disease transmission not only depends on safe and sufficient water, proper sanitation and good hygiene at the household level, but must also include hygiene in the public domain such as public places of work, schools, commerce and recreation as well as the streets and playing fields. They state that the overall levels of hygiene in villages may play an even more important role than in the household¹⁶. Children spend a lot of their time in other households, at school and on the streets, and households can share meals or buy water and food from street vendors. In several studies crowding was reported a risk factor for diarrhoea as well as the number of children per household. Koopman stresses that in schools, in addition to toilets, there are other factors such as person-to-person contact, that are responsible for the transmission of diarrhoea. He argues that interventions in schools are probably more effective than household-based ones; schools having a central role in the diarrhoea transmission of a village because they disseminate the transmission¹⁷.

There are interactions among interventions, and therefore the effect of a particular intervention will not only depend on its own merit, but also on those of the other interventions with which it interacts. Theoretical models suggest that such interactions exist between water supply, sanitation and hygiene interventions. The impact of improvements in water supply, sanitation and hygiene together are greater than the sum of the effects of the interventions alone. Furthermore, if the interactions are strong, the health impact from an improved water supply may depend critically on whether sanitation and hygiene conditions are good or poor^{18,19}. The Villa Carlos Fonseca studies have made it clear that supplying only hardware is not sufficient to reduce the incidence of diarrhoea. Personal, domestic and especially community hygiene plays a crucial role in the transmission of diarrhoeal pathogens. If e.g. a latrine is not used by all members of a family, its impact on the incidence of diarrhoea will significantly be reduced.

A final practical consequence of our studies was the development of the rope-pump technology. It was an unexpected, although logical outcome of our research, based on the results obtained in the water, sanitation and hygiene studies. The hand dug well is the traditional type of water source, that is mostly used in the rural areas of the developing world. The majority of these wells have been dug near the house or in the middle of a group of houses. One can consider these sources as "on the premises". However, drawing water from these sources with a rope and a bucket is an arduous and time-consuming task. Facilitating this task by a rope-pump makes it possible not only for women (who are traditionally the ones who fetch most of the water), but also for children, to draw the water. The time that is needed to get water will be reduced and the total amount of water that is used, will increase. When water becomes easily available, hygienic behaviour can improve. Another positive effect of the rope-pump is that, since the water is so easily drawn, bathing and washing of clothes in the river will diminish considerable. Rivers are highly polluted sources, with pathogens not only from members of the household, but also from animals and other families of the village and villages upstream. Mothers often take the smallest infants with them to the river, where they come into close contact with unfamiliar pathogens. Reducing the amount of time spent in rivers reduces the contact of the child with these potential pathogens. Providing households with their own water source will eliminate the drinking of water that is polluted by other people. Equipping these water sources with rope-pumps will also result in less contaminated water.

The rope-pump can have a real impact on the water and sanitation programmes throughout the developing world. Moreover it is a low cost technology that can easily be maintained and repaired. The technical and cultural aspects have recently been evaluated by the International Water and Sanitation Centre, a WHO Collaborating Centre in the Hague. This evaluation together with our study of the improvement of the water quality has led to a wider recognition of the potential of rope-pump technology. Over 12,000 rope-pumps, which serve at least 10% of the rural population, have already been installed in Nicaragua during the last decade. The National Water Institute of Nicaragua considers it now as the most appropriate pump for the rural areas and a means to improve its

water supplies, as do the regional offices of several multilateral organizations such as UNICEF, WHO, Red Cross and Foster Parents. The rope-pump is also being used in the neighbouring countries Honduras and El Salvador. Other countries of the developing world, such as Ecuador, Sri Lanka and Zimbabwe are setting up production units. A special unit for the transfer of the rope-pump technology to other countries has been set up in Nicaragua. Though the interest from water and sanitation organizations in other poor countries has been large, thus far the transfer of the rope-pump technology has been slow due to limited funds. However it is expected that on short term more funds will become available to support the south-south transfer of this rope-pump technology.

What should we have done differently?

In the Villa Carlos Fonseca studies we have tried to identify risk factors that play a major role in this setting. With hindsight, the case-control study could have been better designed. Some interview questions could have been better adapted to the local situation. Besides diarrhoea as a health parameter, we could also have looked at the nutritional status of the child. A larger sample size would have obtained clearer results. The choice of a community based or a clinic based study might have been discussed more in depth.

We compared the results of the clinic based case-control study with those of the morbidity and mortality survey that we carried out in Villa Carlos Fonseca during the rainy season when diarrhoea incidence is at its highest. In the case-control study children with diarrhoea who presented themselves at one of the health facilities were compared with children who were presented at the same health facilities with other conditions. The distance from the water source and maternal literacy, but not the type of water source or latrine ownership, were identified as risk factors for diarrhoea. In the community study, families with a child under 5 years who had diarrhoea in the two week period before the survey, were compared with families with one or more children under 5 years who had no diarrhoea. In this survey the distance from the water source, and also the type of water source were identified as risk factors for diarrhoea. The type of water source played a more important role when the distance to the water source was shorter, especially when the distance was less than 10 metres. There was a small effect of maternal schooling and no evidence that latrine ownership was associated with diarrhoea.

In our survey we also asked mothers of children with diarrhoea whether they had visited a health centre. Mothers with a domiciliary connection visited a health centre more often than mothers from the group with a hand-dug or unprotected well. This different behaviour could have been the reason that we did not find any relation between the type of water source and the incidence of diarrhoea in the clinic based study. It is, of course, possible that mothers from the domiciliary connection group also brought their children more frequently to a health centre when they had a different problem. The mothers behaviour of bringing a child to a health centre depends on many factors, such as the distance to the facility, education, the type of illness and the socio-economic situation. Not all illnesses will be treated the same by the mothers, and behaviour may differ between cultural and socio-economic groups. As an example: more educated mothers may bring a child with diarrhoea to a health centre sooner than when the child has a respiratory

infection, and mothers who are less educated may do the opposite. This kind of behaviour may result in selection bias. A community-based case-control study would not suffer from this bias.

The type of water source can be considered a proxy for the quality of the water, domiciliary connections having the best water quality, followed by protected wells, whereas unprotected wells and rivers are most contaminated. The time required to draw water from a domiciliary connection is also much shorter than from a hand dug well with a rope and a bucket, which in turn requires less time than fetching water from the river. The type of water source, being a risk factor in the community survey, should not be interpreted as evidence that this is entirely due to the quality of water.

The first water quality study, the inventory of the types of traditional water sources in Villa Carlos Fonseca, and the study of the determinants of the water quantity that was used by the households are examples of appropriate investigations. They were among the first of a still very limited number of studies that look at traditional water supplies and facilities for the disposal of faeces. Many water supply interventions may have had no impact because the people simply continued to use the traditional sources and were not prepared to use and maintain the new water supply. For an intervention to be effective the minimal condition must be that the design takes into account how people actually live and what they consider as appropriate.

The health beliefs study provides evidence of the importance of the local culture. Any health education campaign may be technically impressive, but if it does not have much meaning for the local population, its effect will be limited. Health education, as well as water supply and sanitation interventions, must be culturally appropriate.

In the water quality study of the rope-pumps several things went wrong. Rope-pumps were already installed before we could take baseline data and the rains of that year were almost non-existent. Nevertheless, the results were quite clear. It is a pity that we did not obtain funds for the randomized trial we designed to investigate the effect of the installation of rope-pumps and hygiene education on the incidence of diarrhoea. Although we approached several donors, none was prepared to finance such a study. Around that time, 1990, donors were reluctant to fund yet another study that might turn out to be a failure.

It might have been better to start with an exhaustive literature review of the actual situation of the water supply, sanitation and hygiene in the poorest countries beforehand. Data that are made available through the World Bank and WHO publications are based on national statistics which have limited usefulness without disaggregation. Descriptions and figures of the traditional situation are rare, but can be found in the "grey" literature of the huge amount of reports written for donors, however many of these reports do not describe in detail the situation before the intervention started. Secondly, a literature review of all potential interventions, estimates of their costs and indicators to measure their impact would have been useful. If an appropriate interven-

tion (feasible, and with low costs and high impact) had been identified, such an intervention could have been piloted. To demonstrate its effectiveness on a larger scale an appropriate investigation could have been performed.

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Summary

Summary

In Villa Carlos Fonseca, west of Managua in a rural area of Nicaragua, an integrated programme of diarrhoeal disease research was performed.

The first investigation was a case-control study to examine the relative importance of water-borne versus water-washed transmission mechanisms in childhood diarrhoeal disease. As part of this study the microbiological quality and the amount of water consumed was investigated. Traditional water sources were grossly contaminated whereas piped water sources were much cleaner. A close association between rainfall and faecal contamination was demonstrated. The water of traditional sources was more contaminated in large communities compared to small communities. Factors found to affect domestic water use were household size, site of clothes washing, the type of water source, mother's level of schooling, distance to the water source, wealth, and the ownership of cattle. A decrease in the distance to the water source from 1000 to 10 meters was associated with a clear increase in per capita water consumption. Families where the mother had at least 6 years of schooling used more water than families where the mother had no formal education.

In our case-control study 1229 children under the age of 5 were matched to an equal number of children of the same age presenting with other illnesses unrelated to water and sanitation. In spite of marked differences in water quality between the different types of water supply, no effect was found of the water quality on the diarrhoea morbidity. In contrast, there was a clear association between water availability and diarrhoea morbidity. Children from homes with water supplies over 500 metres from the house had much higher incidence rates of diarrhoea than children from houses with their water supply "on the premises". The ownership of a latrine was not found to be significantly related to diarrhoea morbidity. A mother's level of schooling was inversely correlated with the frequency of diarrhoea in her children.

Next we conducted a prospective follow-up study on the hygiene practices. From the database of the case control study 172 families with a child under the age of 2 years were recruited. Hygiene behaviour was observed and diarrhoea incidence was recorded for 5 months. Of 46 'good' practices studied, 39 were associated with a lower risk of diarrhoea, 5 were unrelated and only for 2 a higher risk was observed. Washing of hands, domestic cleanliness (kitchen, living room, yard) and the use of diapers/underclothes by the child had the strongest protective effect. Schooling and better economic position had a positive influence on general hygiene behaviour. Individual hygiene behaviour appeared to be highly variable.

In order to gather information on traditional health beliefs and practices we performed two studies: one ethnographic and the other epidemiological. In the ethnographic study, 70 mothers with children under 2 years were interviewed. In the epidemiological study, 392 mothers with a child under the age of 5 participated, 216 of whom had had diarrhea in the previous two weeks. The studies confirmed that traditional beliefs and practices

continue to be important and have a direct influence on the manner in which mothers respond to diarrhoea in their children. Popular health beliefs are a mixture of ideas drawn from traditional and modern notions of disease aetiology, prevention and treatment. A good program combines traditional and modern concepts. Mothers will feel motivated to change their habits only if they understand the effect of harmful hygienic practices on their children.

We also performed a literature review of the health impact of water supplies, sanitation and hygiene on the incidence of diarrhoeal disease. There is a reasonable consensus that water quality improvements do not generally have as great an impact on health as interventions which increase the availability of water or provide human faeces disposal facilities. Those interventions that improve hygienic behaviour at the household level and/or the community level, seem to have the greatest impact. Programmes to improve the level of hygiene practices may be highly effective, but depend on the available preconditions such as the mother's level of education, easy access to a reliable water supply and facilities for faeces disposal. Social and cultural factors may also have a reinforcing or a restraining influence.

A further literature review was carried out to identify which interventions are most likely to reduce faecal contamination of wells, waterholes and surface water. The few published studies suggest that upgrading wells is effective through improvements such as a windlass, bucket cage, drainage system, lining, head wall and cover when these are applied together. It is not known, however, how effective individual components of the upgrading are in reducing contamination. The provision of pumps seems to be useful in settings with gross contamination, and tube wells are consistently cleaner than hand dug wells.

A final practical result from our studies was the development of the rope pump technology. Rope pumps are now widely promoted as a low cost, easily maintained means to improve water availability in many developing countries. The hand-dug well is the traditional type of water source that is mostly used in rural areas. Facilitating the task of drawing water through the installation of a rope pump will reduce the time that is needed to get water. The total amount of used water will increase. Our study looked at the well water quality under a variety of different conditions, comparing bucket and rope wells, with wells with a windlass and rope pump wells. Results indicated a strong reduction of the faecal coliform contamination of the well water due to the installation of a rope pump, compared to bucket and rope wells. Other factors found to influence the level of contamination of water in hand-dug wells were rainfall, the number of households using the well, the amount of water extracted daily and the distance of the well to the nearest kitchen. The last three factors probably reflect domestic activities around the well.

On the basis of our empirical studies we conclude that increasing the quantity of water available to people in developing countries can reduce the transmission of diarrhoeal pathogens considerably. Together with other preconditions, such as education, mothers

will be able to develop good hygiene at the personal, domestic and community level. Diarrhoea is a major health problem and affects all infants in the developing world. None of the developing countries has full coverage of adequate water supplies and sanitation facilities, and in general they have poor hygiene at the household as well as at the public level. Improvements of one or more of these factors should increase the health and survival of many infants in these countries.

Samenvatting

Samenvatting

Een integraal diarree-onderzoeksprogramma werd uitgevoerd in Villa Carlos Fonseca, een landelijk gebied ten westen van Managua.

Het eerste onderzoek betrof een case-control studie waarin het relatieve belang van 'water-borne' versus 'water-washed' transmissie-routes van diarree bij kinderen werd onderzocht. Als onderdeel van deze studie werd de microbiologische kwaliteit en de hoeveelheid water gebruikt in het huishouden bestudeerd. Traditionele waterbronnen waren ernstig vervuild, terwijl kraan-aansluitingen veel schoner waren. Er werd een nauwe samenhang tussen regenval en faecale contaminatie aangetoond. Het water van de traditionele bronnen was in de grote dorpen meer vervuild dan in de kleinere. Factoren die de hoeveelheid water, welke in de huishoudens wordt gebruikt, beïnvloedden waren; grootte van het gezin, plaats waar kleren worden gewassen, type waterbron, scholingsniveau moeder, afstand tot de waterbron, inkomen en eigendom van vee. Een afname van de afstand tot de waterbron van 1000 tot 10 meter werd gerelateerd aan een duidelijke toename in de hoeveelheid water gebruikt per hoofd van het gezin. Families waar de moeder minstens 6 jaar lager onderwijs had ontvangen, gebruikten meer water dan families waar de moeder geen opleiding had.

In onze case-control studie werden 1229 kinderen onder de 5 jaar gekoppeld aan een gelijk aantal van dezelfde leeftijd die zich bij dezelfde gezondheidspost met een andere ziekte, welke niet gerelateerd was aan water en sanitatie, hadden gepresenteerd. Ondanks grote verschillen in de kwaliteit van het water van de diverse soorten waterbronnen werd er geen effect van deze waterkwaliteit op de diarree-morbiditeit geconstateerd. In tegenstelling hiermee werd een duidelijke samenhang gevonden tussen de bereikbaarheid van het water en de diarree-morbiditeit. Kinderen van gezinnen waar de waterbron op meer dan 500 meter van het huis ligt, hadden veel hogere diarree-incidenties dan zij waar zich de waterbron in of naast het huis bevindt. Het beschikken over een latrine was niet significant gerelateerd aan diarree morbiditeit. De frequentie van diarree bij kinderen was invers gerelateerd aan het niveau van de opleiding van de moeder.

Vervolgens werd een prospectieve follow-up studie betreffende hygiëne gebruiken uitgevoerd. Er werden 172 families met een kind onder de 2 jaar geselecteerd van de dataset van de case-control studie. De hygiëne gebruiken werden geobserveerd en de diarree-incidentie werd gedurende 5 maanden gemeten. Van de 46 bestudeerde 'goede' gebruiken, waren er 39 gerelateerd aan een lager diarree-risico, 5 waren niet gerelateerd en alleen bij 2 werd een hoger risico geobserveerd. Handen wassen, huishoudelijke hygiëne (keuken, woonkamer en erf) en het gebruik van luiers/ondergoed door het kind had het sterkste beschermende effect. Opleiding en een betere economische positie hadden een positieve invloed op het algemene hygiëne gedrag. Het hygiëne gedrag bleek per individu het meest variabel.

Om informatie te verzamelen over de traditionele ziekte concepten werden twee studies uitgevoerd: een etnografische en een epidemiologische studie. In de etnografische studie

werden 70 moeders met kinderen onder de 2 jaar geïnterviewd. Aan de epidemiologische studie namen 392 moeders deel met een kind onder de 5 jaar waarvan er 216 diarree hadden gehad in de twee voorafgaande weken. De studies bevestigden dat traditionele ziekte concepten en gebruiken nog steeds belangrijk zijn en een directe invloed hebben op de manier waarop moeders reageren op diarree van hun kinderen. De lokale ziekte concepten zijn een mengsel van ideeën afkomstig van de traditionele en de moderne denkbeelden betreffende ziekte-oorsprong, -preventie en -behandeling. Een goed programma combineert de traditionele en moderne concepten. Moeders zullen alleen dan zich gemotiveerd voelen hun gebruiken te veranderen, wanneer ze begrijpen wat het schadelijke effect van bepaalde hygiëne gewoontes op hun kinderen kan zijn.

Wij voerden ook een literatuur-onderzoek uit betreffende het gezondheidseffect van water, sanitaire voorzieningen en hygiëne op het voorkomen van diarree. Er bestaat een redelijke consensus dat de toename van de kwaliteit van water over het algemeen niet zo'n groot effect heeft als interventies die de bereikbaarheid van water verbeteren of sanitaire voorzieningen leveren ter hygiënische verwijdering van humane faeces. Die interventies die het hygiëne gedrag zowel in het huishouden, als op het openbare niveau verbeteren schijnen de grootste invloed te hebben. Programma's ter verbetering van de hygiëne gebruiken zouden wel eens hooglijk effectief kunnen zijn, maar dit zal ook afhangen van de bestaande omstandigheden zoals het opleidingsniveau van de moeder, toegang tot een betrouwbare waterbron en sanitaire voorzieningen. Sociale en culturele factoren kunnen een versterkende of een remmende invloed hebben.

Ook werd er een literatuur-onderzoek uitgevoerd ter identificatie van die interventies die mogelijk tot vermindering van de faecale contaminatie van putten, watergaten en oppervlaktewater kunnen leiden. De weinige gepubliceerde studies suggereren dat verbetering van putten effectief is indien tegelijkertijd een windas, een kooi om de emmer, een drainage systeem, wandbekleding in de put, putranden en een deksel worden aangebracht. Het is echter niet bekend hoe sterk iedere individuele component op zich de vervuiling vermindert. Het plaatsen van pompen schijnt nuttig te zijn in die omstandigheden waar er ernstige vervuiling is en daarnaast zijn geboorde putten gemiddeld veel schoner dan hand-gegraven putten.

Een uiteindelijk praktisch resultaat van onze studies was de ontwikkeling van de touwpomp-technologie. Er wordt nu uitgebreid bekendheid gemaakt voor de touwpomp als een goedkope en gemakkelijk te onderhouden techniek om water in veel ontwikkelingslanden beter bereikbaar te maken. De hand-gegraven put is de traditionele waterbron die in de rurale streken het meest wordt gebruikt. Het vergemakkelijken van de taak om water te putten door middel van de installatie van een touwpomp vermindert de tijd die nodig is om water te halen. De totale hoeveelheid water die wordt gebruikt zal hierdoor toenemen. Onze studie onderzocht de kwaliteit van het water onder verschillende omstandigheden; waarbij de kwaliteit van water opgehaald met een touw en emmer, met een windas en met een touwpomp werd vergeleken. De resultaten tonen een sterke afname van de vervuiling van het water met faecale coliformen ten gevolge van de installatie van een touwpomp, vergeleken met het water dat geput werd met een touw en

emmer. Andere factoren die de mate van vervuiling in hand-gegraven putten beïnvloeden zijn regenval, het aantal huishoudens dat de put gebruikt, de dagelijkse hoeveelheid water onttrokken uit de put en de afstand tot de dichtbijzijnde keuken. Deze laatste drie factoren geven waarschijnlijk de huishoudelijke activiteiten rondom de put weer.

Op basis van onze empirische studies kunnen we concluderen dat een toename in de hoeveelheid water beschikbaar, de overdracht van diarree-pathogenen onder de bevolking in ontwikkelingslanden aanzienlijk doet verminderen. Tezamen met andere positieve omstandigheden zoals opleiding, zal dit moeders in staat stellen een goed hygiënisch gedrag te ontwikkelen, zowel persoonlijk, in het huishouden als in haar woonomgeving. Diarree is een groot gezondheidsprobleem en betreft alle kinderen in ontwikkelingslanden. In geen enkel ontwikkelingsland zijn de voorzieningen voor water- en sanitatie volledig en over het algemeen is er een beperkte hygiëne, zowel in het huishouden als op het openbare niveau. Verbeteringen van een of meer van deze factoren zal de gezondheid en overlevingsmogelijkheden van vele kinderen in deze landen verhogen.

Resumen

Resumen

En la Villa Carlos Fonseca, ubicada en la zona rural de Nicaragua, al oeste de Managua, fue llevado a cabo un programa integral de investigación en diarrea.

La primera investigación era un estudio de casos y controles para examinar la importancia relativa del modo de transmisión de la diarrea en los niños; directa a través de agua bebida o a través de la contaminación indirecta (falta de higiene). La calidad microbiológica y la cantidad de agua usada fueron investigadas como parte de este estudio. Fuentes de agua tradicionales estaban fuertemente contaminadas, mientras conexiones domiciliarias estaban mucho más limpias. Se demostró una fuerte relación entre la lluvia y la contaminación. El agua de las fuentes tradicionales estaba más contaminada en las comunidades grandes que en las comunidades pequeñas. Factores que afectan la cantidad de agua usada en la casa eran: número de miembros de la familia, lugar de lavar ropa, tipo de fuente de agua, nivel de escolaridad de la madre, distancia a la fuente de agua, posición económica y tenencia de ganado. Una disminución en la distancia a la fuente de agua de 1000 a 10 metros era asociada con un claro aumento en la cantidad de agua usada per cápita. Familias en donde la madre tenía por lo menos 6 años de escolaridad usaban más agua que familias en donde la madre no tenía ninguna educación.

En nuestro estudio de casos y controles 1229 niños menores de 5 años eran apareados con una misma cantidad de niños de la misma edad que se habían presentado con otra enfermedad que no era relacionada con agua y saneamiento. A pesar de las grandes diferencias en la calidad del agua entre los diferentes tipos de fuentes de agua, no se detectó ningún efecto en la incidencia de la diarrea debido a la calidad del agua. Al contrario de esto, se encontró una clara asociación entre la disponibilidad del agua y la incidencia de diarrea. Niños de familias con una fuente de agua a más de 500 metros de la casa tenían incidencias de diarrea más altas que niños de las familias con una fuente de agua dentro de su casa o en el patio de la misma. La existencia de una letrina en la casa no era relacionada significativamente con la morbilidad de diarrea. El nivel de escolaridad de la madre tenía una correlación invertida con la frecuencia de la diarrea en sus niños.

Posteriormente realizamos un estudio prospectivo en prácticas higiénicas. De la base de datos del estudio de casos y controles se escogió 172 familias con un niño menor de 2 años. Se observó el comportamiento higiénico y se anotó la incidencia de la diarrea durante 5 meses. De las 46 prácticas higiénicas estudiadas, 39 eran asociadas a una incidencia de diarrea más bajo, 5 no tenían relación y solamente con 2 se observó una incidencia de diarrea más alta. El lavado de manos, higiene doméstica (cocina, sala y patio) y el uso de pañales/calzoncillos por el niño tenían el efecto más grande para proteger contra la diarrea. La educación y una mejor posición económica tenían una influencia positiva en el comportamiento higiénico en general. El comportamiento higiénico en la misma persona era altamente variable.

Realizamos dos estudios para recoger información sobre creencias y prácticas de salud tradicionales: un estudio era etnográfico y el otro epidemiológico. En el estudio etnográfico

fico se entrevistó a 70 madres con niños menores de 2 años. En el estudio epidemiológico participaban 392 madres con un niño menor de 5 años, de los cuales 216 tuvieron diarrea en las dos semanas anteriores. Los estudios confirman que creencias y prácticas tradicionales siguen siendo importante y tienen una influencia directa sobre la manera en que las madres responden a la diarrea en sus niños. Creencias de salud populares son una mezcla de ideas que vienen de conocimientos tradicionales y modernos sobre la causa, prevención y tratamiento de una enfermedad. Un buen programa combina estos conceptos tradicionales y modernos. Así las madres podrían sentirse motivadas a cambiar sus costumbres si ellas entienden el efecto que pueden tener las malas prácticas higiénicas en sus niños.

También hicimos una revisión de literatura sobre el impacto en salud de agua, saneamiento e higiene sobre la incidencia en diarrea. Hay bastante consenso que el mejoramiento en la calidad del agua no causa generalmente un impacto tan grande como las intervenciones que aumentan la disponibilidad del agua o proveen facilidades para la eliminación de las heces humanas. Las intervenciones que mejoran el comportamiento higiénico a nivel doméstico y/o a nivel de la comunidad parecen tener el impacto más grande. Un programa para mejorar las prácticas higiénicas puede ser altamente efectivo, pero depende de las condiciones existentes, como el nivel de la escolaridad de la madre, el fácil acceso a una buena fuente de agua y facilidades para la eliminación de las heces. Factores sociales y culturales pueden también tener una influencia que refuerce o disminuya el efecto.

Se realizó otra revisión de literatura para identificar cuales intervenciones podrían reducir la contaminación fecal de los pozos, charcos y agua superficial. Los pocos estudios publicados sugieren que mejorar los pozos es efectivo cuando se combinan mejoramientos como un malcate, una jaula de hierro alrededor del balde, un sistema de drenaje, revestimiento del pozo, un brocal y una tapa. Pero no se sabe el efecto por aparte de cada componente en reducir la contaminación. La instalación de bombas de agua parece ser útil en los pozos con bastante contaminación. Los pozos perforados son casi siempre más limpio que los pozos excavados a mano.

Un resultado final y práctico de nuestros estudios era el desarrollo de la tecnología de la bomba de mecate. Ahora las bombas de mecate son promocionadas ampliamente como un medio de bajo costo y de fácil mantenimiento para mejorar la disponibilidad del agua en muchos países en vías de desarrollo. Los pozos excavados a mano son el tipo de fuente de agua más común en las áreas rurales. Facilitar la tarea de halar agua por medio de la instalación de una bomba de mecate reducirá el tiempo que se necesita para obtener el agua, lo cual aumentará la cantidad total de agua usada. Nuestro estudio investigó la calidad del agua de los pozos bajo diferentes condiciones, comparando la calidad del agua de los pozos con mecate y balde, con los pozos con malcate y con los pozos con una bomba de mecate. Los resultados indican una fuerte reducción de la contaminación por coliformes fecales del agua en los pozos, debido a la instalación de una bomba de mecate, comparado con el agua de los pozos con mecate y balde. Otros factores que influenciaban el nivel de la contaminación del agua en los pozos eran la lluvia, el número de

casas que utilizaban el pozo, la cantidad de agua extraída cada día y la distancia del pozo a la cocina más cercana. Los últimos tres factores reflejan probablemente las actividades domésticas alrededor del pozo.

En base a nuestros estudios empíricos podemos concluir que aumentar la cantidad de agua disponible a la gente de los países en vías de desarrollo reducirá la transmisión de patógenos diarreicos considerablemente. En conjunto con otras condiciones, como la educación, las madres serán capaces de desarrollar buenos comportamientos higiénicos personales, domésticos y a nivel comunitario. La diarrea es un problema de salud mayor y afecta a todos los niños de los países en vías de desarrollo. Ninguno de los países en vías de desarrollo tiene una completa cobertura de facilidades de agua y saneamiento, y por lo general la higiene es pobre a nivel doméstico y a nivel comunitario. Mejorar uno o más de estos factores puede mejorar la salud y la sobrevivencia de muchos niños en estos países.

Summary of references in alphabetic order

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After each reference the number of the chapter and that of the reference are given; where the references were ordered alphabetic the number of the chapter and "alph" are indicated.

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Curriculum Vitae

Curriculum Vitae

Anna Cornelia Gorter was born August 20, 1953 in Roosendaal, Netherlands. She grew up in Roosendaal and finished there her secondary school at the Gertrudis College (HBS-B) in 1971. She studied medicine at the University of Amsterdam where she obtained her medical degree in 1980. In order to qualify to be posted abroad as a medical doctor by the Department of International Development of the Dutch Government she specialized during a period of one year in general surgery and obstetrics in the Willem-Alexander hospital in 's Hertogenbosch, Netherlands. Then she worked a year at the municipal methadone program for drug-addicts in Amsterdam. The Certificate of Tropical Medicine was obtained in 1982 at the Royal Institute of the Tropics in Amsterdam. In 1983 she left for Nicaragua to work as a medical officer at the rural health area Villa Carlos Fonseca. In 1986 she started her diarrhoeal disease research. Since 1989 she has also been involved in the development of programmes for the prevention of AIDS and Sexually Transmitted Diseases. She is still living in Nicaragua with her husband. They have two children.

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Appendix:

- 1. The Nicaraguan rope pump**
- 2. Why do child mortality rates fall? An analysis of the Nicaraguan experience**

The Nicaraguan rope pump

by Peter Sandiford, Henk Alberts, Juan Guillermo Orozco, and Anna Gorter

Despite numerous setbacks, the rope pump's development in Nicaragua has finally fulfilled its promoters' expectations. Even pumps installed during an emergency in an area without access to spare parts are still working.

ALTHOUGH THE FIRST rope-and-washer pumps appear to have been introduced into Nicaragua about 20 years ago, it was not until 1983 that a Belgian technician named Jan Haemhouts seriously began to develop the rope pump in Nicaragua. He had been involved with a peasant self-development project in Haiti in which the rope pump was one component, but the political situation there finally made further work impossible and he left the country. He believed that the rope pump, a technology that could be produced by peasants themselves, could serve as a catalyst around which the people could organize themselves to resolve their problems and improve their lives. His experience in Haiti, however, had convinced him that such a process could only be successful when set within a supportive political environment.

He turned instead to revolutionary Nicaragua, which at the time seemed to be the ideal setting to try out these ideas. He felt that before the rope pump could gain acceptance it needed to be developed to a stage where it could be presented as a highly reliable yet inexpensive water supply — in other words, as an appropriate technology. The development of the rope pump began in Nicaragua at the Appropriate Technology Research Centre of the Agrarian Reform Institute (CITA-INRA). CITA-INRA brought together professionals who were enthusiastically promoting a whole host of technologies including biogas, windmills for both electricity generation and water pumping, and hydraulic rams, and put them to work on the rope pump. Nicaraguan versions of the rope pumps evolved and a major effort was

made to demonstrate that peasants were both interested enough and capable of building the pumps themselves. Training materials, including a video and a cartoon booklet, were produced at this time.

Despite some notable successes, CITA-INRA was disbanded in 1985, as civil war began to take its toll on the country's fragile economy. By that

stage serious limitations had become evident. Too much effort had been put into the scientific development of technologies, while insufficient attention had been given to their dissemination within the ministries and the institutions responsible for their application on a large scale. Nevertheless, the experience in CITA-INRA had demonstrated the acceptability of the rope pump within the Nicaraguan peasantry, and those who had been involved with it from the early stages continued to seek opportunities for its further promotion as a component of the rural development projects being undertaken at that time.

The fact that rope pumps are still being made by local carpenters in the

The Nicaraguan rope pump has overcome numerous setbacks and is now a popular and reliable technology.

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This one rope pump provides more than enough water for this Nicaraguan family.

Figure 1. A typical design for a rope pump for use in a vertical well. (Figures 1 to 4 are from How to make a rope-and-washer pump, IT Publications, 1990.)

area surrounding the CITA-centre, without any institutional promotion since 1985, demonstrates the impact of those activities during that period. An accurate estimate is impossible to obtain because the pumps were installed all over Nicaragua and made by different people, but well over a hundred pumps must have been produced by these artisans.

Try again

A significant turning point in the fortunes of the rope pump took place in 1987. Juan Guillermo Orozco, a Colombian sanitary engineer working as a consultant in the recently established Environmental Engineering Programme (INGAM) of the National Engineering University, together with Haemhouts, was looking for opportunities to continue to promote the rope pump in a setting without the problems of war and institutional politics which had plagued the project in CITA-INRA. They started work again with a small family-based co-operative in Monte Fresco, a village some 30km from the capital, Managua. The setting appeared to be perfect — the San José co-operative had been founded by peasants who did not have sufficient land to work on, and who had therefore taken to producing brooms, brushes, and other domestic articles. The co-operative had some equipment and staff and it seemed that, with a little training and investment, it could produce rope pumps and perhaps even

realize Haemhouts' vision of peasant self-advancement. The idea was that the rope pump would be just one, though the first, of several technologies which would be developed and then produced on a larger scale in the co-operative.

Seeding finance of about \$10 000 was obtained from the governments of New Zealand and Holland. The intention was to use this money to develop, produce, and install one thousand pumps in the hand-dug wells in the surrounding area. Once built, it would be possible to study and perfect the pump.

The project quickly made some significant advances. In the initial stage a number of technical improvements were made to the prototype pumps, effectively transforming them from a 'Heath Robinson' endeavour into a truly appropriate technology, although still lacking in important respects. The project was starting to stagnate in much the same way that it had in CITA-INRA, however — over 50 prototypes had been made without anyone daring to take the plunge and start production on a commercial scale.

It was an ill wind, however, that blew good fortune to the project. In September 1988 hurricane Juana struck Nicaragua, devastating much of the Atlantic coast of the country. A total of about 200 rope pumps were sold to the international organizations which were providing emergency aid to the victims of the disaster on the eastern seaboard. For the first time, the co-operative was forced to enter into production of the rope pump on a significant scale.

Work under pressure

It did so with considerable success. Interestingly, at least 75 per cent of

The rope pump can even be attached to a small engine if large quantities of water are needed.

those pumps were still functioning perfectly two years after their installation, despite the fact that no backup had been provided and that the supply of replacement parts to the isolated Atlantic coast is notoriously difficult. The causes of failure in those that did break down have now been identified and have been resolved in the more

recent improvements to the design.

Unfortunately success does not always breed success. At this point, there emerged a serious rift between the philosophies of the two key protagonists of the rope pump project: one saw a role for the university in providing technical assistance and an opportunity for the environmental engineering students to learn from the practical application of appropriate technologies, while the other felt that technical assistance was unnecessary and that the peasants themselves had sufficient innovative ability to develop the pump to its final stage. According to the latter view, the involvement of the students would only detract from potential innovation. While one felt that the future for the project lay in selling pumps on a commercial basis, the other thought that this would destroy the potential of the rope pump to serve as a catalyst for peasant self-advancement. In the end, these philosophical differences led to the complete collapse of the relationship between the San José Co-operative and the Environmental Engineering Programme.

Figure 2. If used in a vertical lined well, the pump will need a suitable outlet spout. If a pre-formed spout is not available, this design can be used.

Figure 3. The rope pump can be used to deliver water for irrigation to nearby fields.

New supporters

Before that took place, however, both UNICEF and a Dutch volunteer organization had seen the potential success of the rope pump project. The Dutch group, who were undertaking a water and sanitation development project in one of the regions of Nicaragua, opted to use the rope pumps rather than the imported handpumps that they had originally intended to use. In this project the pumps were to be installed on communal wells, and the organization felt it important to ensure that microbiological quality was adequate. They therefore focused on ways to prevent the introduction of external contaminants through, for example, the use of well-head covers.

Meanwhile, UNICEF planned a new project which was to be executed by the Environmental Engineering Programme. The rope pump was initially a key component of this project, but in time it was relegated to an increasingly peripheral role as it was considered inappropriate for a university to be involved in industrial production. The university's role was restricted to one of determining guidelines and producing prototypes.

By this stage the co-operative was no longer producing rope pumps — it had never developed the skills to market the pump — and the university had effectively lost interest in working with the co-operative. Formal agreements between the co-operative and the university had failed to provide an adequate foundation for further work. Neither the co-operative nor the university had the skills required to market the pump effectively, to provide the backup services, or to manage the resources involved in production.

Unable to rely on the continued supply of the rope pumps, the INGM/UNICEF project decided in early 1990 to discontinue promoting the pump and to concentrate on their new role in developing policy guidelines. This left two rope pump promoters without jobs and a number of disgruntled families in the area who had been promised rope pumps by the UNICEF/INGM project.

In February 1990 an historic meeting took place between the two pump promoters, the UNICEF/INGM's project administrator (who had also been laid off), and a Dutch physicist who had previously worked in Nicaragua producing wind-driven water

pumps. The feeling which pervaded this meeting was 'let's do it ourselves — independently of any bureaucracy'.

Here started what became, in August 1992, Bombas de Mecate S.A. (Rope Pumps Ltd), a small cottage industry producing rope pumps for the Nicaraguan population. Beginning on a small scale it placed a heavy emphasis in the initial stage on promoting the pump, taking advantage of the various fairs and exhibitions about the country to demonstrate its worth and thereby obtain sales. Advertisements in newspapers and on the radio were also used. Now it employs a dozen workers and installs on average 60 rope pumps each month. As the pump became better known, the need for active marketing diminished and most sales are currently derived from the recommendations of other pump owners. Sales have increased steadily and Bombas de Mecate is now operating commercially without any external subsidies. There are plans to establish branches in different parts of the country and perhaps even outside of Nicaragua. The Dutch group has also had some success. Following the example of Bombas de Mecate, they have started to sell the pumps on a commercial basis. Some of the components of their rope pumps are sold to them by Bombas de Mecate.

So what are the lessons from this story? Why has the rope pump proved such a successful technology while other hand pumps have been such dismal failures? Why has the rope pump so stubbornly re-emerged from the institutional mires which have threatened to sink it? Surely this is the test of a truly appropriate technology — one which overcomes the inevitable obstacles which are placed in its path. The ease of operation, low cost, simplicity of maintenance, ready availability of spares, and high efficiency are undoubtedly important factors. They have perhaps ensured that the rope pump did not fade into obscurity in Nicaragua. ●

Figure 4. Tips for constructing your own rope-and-washer pump.

Why Do Child Mortality Rates Fall? An Analysis of the Nicaraguan Experience

ABSTRACT

A comprehensive review of available sources of mortality data was undertaken to document the changes that have occurred in infant mortality in Nicaragua over the last three decades. It was found that a rapid fall in infant mortality commenced in the early 1970s and has continued steadily since. Trends in several different factors which might have led to this breakthrough were examined including: income, nutrition, breastfeeding practices, maternal education, immunizations, access to health services, provision of water supplies and sanitation, and anti-malarial programs. Of these, improved access to health services appears to have been the most important factor. At a time when the number of hospital beds per capita was dropping, increasing numbers of health care professionals, particularly nurses, were becoming available to staff primary health care facilities built in the 1960s. These were provided at least partly in response to the growing political turmoil enveloping the nation at that time. Certain Nicaraguan cultural attributes may have added to the impact of the reforms. Efforts in the field of public health made since the 1979 insurrection appear to have maintained the decline in child mortality. (*Am J Public Health* 1991; 81:30-37)

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Introduction

Poor child health in developing countries continues to be a source of concern.¹ In recent years it has become apparent that while poverty is probably the major factor affecting survival in the early years of life, there are undoubtedly other influences playing an important role. Some countries, in spite of a low per capita gross national product, have succeeded in achieving mortality levels close or equal to those of the industrialized world. In contrast, there are others with poor levels of child health despite enjoying relatively high per capita incomes.² Efforts have recently been made to identify the factors beside socioeconomic status which are determinants of infant mortality. In 1985, the Rockefeller Foundation sponsored a conference which studied the striking mortality reductions in Kerala State (India), Sri Lanka, Costa Rica, and China.³ In each case, mortality has fallen sharply over a relatively short period leading to high life expectancy relative to national income. Seven conditions were purported to be essential to the observed improvements: female autonomy, education (especially female), the provision of accessible health services, a mechanism to guarantee the efficient operation of health services, an adequate minimal standard of nutrition, universal immunization, and a commitment to the establishment of effective antenatal and obstetric services.²

Nicaragua is another country which has experienced a recent breakthrough in child mortality. This article describes that breakthrough and looks at its relationship with some of the factors alleged to be important determinants of child mortality. It is hoped this work serve as a model for the

type of intersectoral data analysis advocated recently by de Kadt.⁴

Methods

Seven different sources of data were identified which could provide time-located estimates of infant mortality in Nicaragua from 1960 to 1986.⁵⁻¹¹ A brief description of each source of data is given in the Appendix. Except for data obtained from the Civil Register, the infant mortality estimates were derived using the Brass technique based on the ratio of surviving to ever born children of mothers classified by five-year age group. The rationale behind this method is that the proportions dead of ever born children for women of a certain age correspond to discrete child survival probabilities. These survival probabilities can be used to calculate infant mortality rates (IMRs) if one assumes a typical age pattern of mortality. In this case the Coale-Demeny 'West' model of mortality was used.¹²

Variations of the Brass method have been developed which allow the estimation of trends in mortality change, recognizing that the deaths in children born to

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women ages 15–19 years have occurred more recently than the deaths in children of women ages 45–49. The Trussell method, which was employed in this analysis is one such variant.¹³ It provides time locations for the infant mortality estimates obtained from each five-year age group of mothers.

Estimates of infant mortality from the death register were calculated by dividing the number of deaths registered in each year by the projected population under the age of one. Death registration is well known to be variable and incomplete so these figures were not used in further calculations. However, the relatively low rate of omission for birth registration allows a more accurate estimation of the IMR by asking about the survival of preceding births at the time of registration. The data for 1986 (SINEVI-86) were analyzed in this way by the Centro Latino-Americano de Demografía (CELADE).¹¹

There are a number of factors which are believed to be important determinants of child mortality. These include: income, nutrition, maternal education, breastfeeding, immunization coverage, the provision of health services, access to water supplies and sanitation, malaria control, as well as certain cultural attributes of the population. Trends in these factors were examined and related to the observed changes in infant mortality in Nicaragua from 1960 to 1989. Wherever possible, data were obtained from the original sources in Nicaragua by visiting libraries and documentation centers in government ministries and institutions.

Data on per capita Gross National Product (GNP) were obtained from an analysis performed by the National Autonomous University of Nicaragua.¹⁴ It was not possible to accurately quantify changes in income distribution.

An assessment of trends in child nutritional status was based on three surveys on nationwide samples of children in 1966, 1977–8, and 1986.^{15–17} Height for age was used as the indicator of nutritional status as it was the only one measured in all three surveys. In two of the surveys,^{15,16} the children measured were under the age of 5, in the third they were school children ages 6–9 years. Figures for food production and caloric intake were derived from World Bank¹⁸ and United Nations Food and Agricultural Organization¹⁹ statistics, respectively. The frequency of breastfeeding in 1977 and 1988 was estimated from two ad hoc surveys performed in Managua.^{20,21}

Levels of illiteracy in Nicaragua were obtained from the censuses of 1950,²²

FIGURE 1—The trend in Nicaraguan infant mortality by data source, 1956–86

1963,²³ and 1971¹⁵ and from the EDENIC-78 and ESDENIC-85 surveys.¹¹ Rates were calculated for the total population ages 10 years and over, for the urban and rural populations, and for women ages 15–44 years.

An analysis of Ministry of Health cause of death statistics by CELADE documents changes in death rates in children due to immuno-preventable diseases.¹¹ These were compared with an indicator of vaccination coverage, estimated by dividing the Ministry of Health figures for the annual number of inoculations by the population of children under the age of five for that year.

There have been several analyses of Nicaragua's health system, mostly comparing the situation before and after the 1979 insurrection.^{24–27} These were reviewed and combined with statistics

from the health sector^{10,28–30} (public and private) to obtain an overview of the trends in the provision of health services—both as infrastructure and as human resources—from 1960 to 1985.

National statistics were used to determine what changes had taken place in domestic water supply and sanitation facilities.^{10,30} Figures for latrine construction were taken from Ministry of Health records.²⁸ An analysis by Garfield and Vermund³¹ and national records of laboratory tests for malaria were used to look at trends in the incidence of malaria.

Results

Infant Mortality Estimates

Figure 1 shows the infant mortality estimates from each of the aforemen-

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tioned sources plotted against time. Estimates from ESDENIC-85, SINEVI-86 and the 1971 Census, the three largest databases, give a consistent profile of the trend in mortality. Moreover, the IMRs from the sentinel sites study agree remarkably well with those of ESDENIC-85. There is some divergence in the mortality estimates from EDENIC-76, particularly for the early 1970s but these are based on data from a small number of women and hence this may be due to sampling error. The rates calculated from death registration are incompatible with the other estimates, a reflection of gross inadequacies in coverage of this system. They are not used in further analyses.

A weighted average of infant mortality estimates from the 1971 census, the EDENIC-76 and ESDENIC-85 surveys, the SINEVI-86 analysis of birth registration and the sentinel sites study was made

for each two-year interval. Rates obtained from women ages 15-19 years were not included as these are well known to be unreliable.¹³ The results are plotted in Figure 2. Figure 3 presents the same data plotted on a logarithmic scale which more appropriately portrays the change in the rate of decline. Taken as a whole, the studies indicate that the rate of fall in infant mortality, which was slow in the 1960s, increased sharply in the early 1970s, and that this rapid decline was still continuing in 1986. The infant mortality rate drops on average by 4.7 deaths per 1,000 live births for each year from 1974 to 1986. Assuming a 'West' mortality schedule, this is equivalent to an annual increase in life expectancy of 0.75 years each year over this 12-year period.

Figure 4 presents urban and rural IMRs from the 1971 Census and ESDENIC-85. Changes in the definitions of

'urban' and 'rural' and internal migration make interpretation difficult but there is no clear evidence that in Nicaragua the breakthrough was more pronounced in rural areas than in urban areas.

Differential infant mortality rates according to levels of maternal education are provided by the CELADE analysis. In the three time periods examined—1966-67, 1973-74, and 1982-83—infant mortality rates for mothers with secondary or higher education were considerably lower than for mothers with primary or no formal education. The results suggested that this differential narrowed over the period in question (data not shown).

Explanations for the Decline in Child Mortality

How can this sharp drop in child mortality be explained? In the first place, it should be recognized that more than one factor may be involved. The reason that mortality started to fall may be different from the reason that it continues to fall. Since this is not a controlled experiment, causes can easily be confused with effects, and one is always left in doubt as to what would have happened in a different set of circumstances. Nevertheless, the Nicaraguan case has some very interesting features which make it worth examining in greater detail.

Income—The observed infant mortality decline in Nicaragua does not correspond to a rise in general living standards. Per capita GNP rose rapidly in the early 1960s but flattened off in the 1970s before falling sharply in the 1980s. This fall may have been offset somewhat by a more equal distribution of wealth following the insurrection (as a result of the wages policy, food subsidies and rationing, price controls, and rent controls), but there are insufficient data to quantify changes in income distribution over this period.

Nutrition—In 1966, 36 percent of children under the age of 5 were found to be below two standard deviations in the reference range for height for age. In the survey performed from 1977 to 1978, 26 percent of children under the age of 5 were below two standard deviations for height for age and in 1986 the corresponding prevalence of stunting in first grade school children (ages 6-9 years) was 22 percent. Although Nicaragua has high rates of primary school attendance, poor children tend to start later than the rest. This produced an age bias in the results of the 1986 survey such that in 6-year-old first grade children the prevalence of low height for

FIGURE 3—The trend in Nicaraguan infant mortality: 1956-86 (weighted averages) plotted on a logarithmic scale (base 10)

age was only 14.5 percent compared with 32.7 percent for 9-year-old first grade pupils.

Despite the deficiencies in the available data, it would seem reasonable to conclude that nutritional status in Nicaraguan children improved steadily from 1966 to 1986, but the factors leading to this improvement are uncertain. Food production in 1986 was only 70 percent of what it was in 1967 having fallen sharply from its peak in 1978. The number of food calories per head of population dropped from 2,410 in 1970 to 2,344 in 1975 and then to 2,258 in 1980, recovering slightly by 1983 to 2,304.

On the other hand, a variety of programs and activities aimed at improving child nutrition already existed in 1970.³² These were expanded in 1973 in response to the threat posed by the 1971 drought and the 1972 earthquake. A milk distribution program of the Ministry of Public Health was in operation since the 1960s but was gradually abandoned in the late 1970s. It was recommended for several years following the 1979 insurrection along with other policies aimed at estab-

lishing an adequate nutritional standard. These included food subsidies, rationing, and supplementary feeding programs for pregnant women and malnourished children.

Breastfeeding—The limited data available suggest that there has been no increase, and perhaps a decrease occurred in the average duration of breastfeeding in Nicaragua over the period of rapidly declining child mortality. In 1977, 58 percent of mothers in Managua were breastfeeding their children for at least six months. In 1988, only 33 percent of children between three and five months of age were still receiving breast milk.

Maternal Education—The changes in the rate of illiteracy in Nicaragua are summarized in Table 1. The tendency has been for illiteracy to decrease throughout the period from 1950 to 1985. The overall drop in illiteracy is greater than the individual falls in urban and rural areas because of migration to the town and cities. The slowest rate of change in the overall prevalence of illiteracy was observed between 1971 and 1978. Between 1978 and 1985 there was a marked drop in the prev-

alence of illiteracy, mainly as a consequence of the 1980 National Literacy Crusade and the extensive adult education program which followed.

Immunizations—Mortality due to diseases preventable by immunization in the ages 1-4 dropped from 21 per 10,000 in 1975 to 3 per 10,000 in 1986 (or from 17 percent to 4 percent as a proportion of total mortality in this age group). Unfortunately, the poor quality of the statistics did not permit a similar analysis for children under one year of age.

Table 2 shows the change in rates of immunization over the period from 1970 to 1985. Prior to 1979 rates of vaccination coverage varied widely as periodic campaigns were launched in response to cyclic epidemics of immuno-preventable disease. Since 1979 coverage has been higher and shown less variation. The participation in massive nationwide vaccination campaigns of large numbers of voluntary health workers in the years immediately following the insurrection was probably the main factor in this improvement.

Health Services—In comparison with other developing countries, Nicaragua's health system suffered more from maldistribution of resources than from a lack of investment. Health service infrastructure and personnel were concentrated in the cities and particularly in the capital. In the 1960s and 1970s, efforts were made to redress this imbalance and improve access to health care. A USAID loan of \$US 2.2 million was received in 1965 to set up 55 health centers and provide outreach programs in rural areas. By 1974 there were 33 hospitals, 93 health centers and 38 health posts spread throughout the country, and the Rural Mobile Health Program provided care to remote areas. More primary health care facilities were built in the first years following the insurrection.

Although considerable infrastructure was already installed by 1973, an evaluation of the 55 health centers built from USAID loan found low utilization rates owing to the lack of personnel, supplies, and management support. Two further USAID grants were made in the mid-1970s to correct these deficiencies.

In contrast to the growth in primary health care facilities, there was a general deterioration in hospital care since the early 1970s. The number of hospital beds per capita peaked at 2.6 in 1971 and has gradually dropped since. The National Social Security Institute (INSS), a health care provider, grew slowly but steadily from 1960 to 1980. In 1963, only 4.1 per-

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FIGURE 4—The trend in Nicaraguan infant mortality: Urban versus rural, 1956–82

TABLE 1—Trends in Nicaraguan Illiteracy Rates, 1950–85

Year	Total ^a	Urban ^a	Rural ^a	Women ^b
1950	62%	30%	80%	61%
1963	49%	21%	70%	50%
1971	42%	18%	66%	43%
1978	39%	17%	63%	38%
1985	25%	13%	40%	26%

^aRefers to the population ages 10 years and over.
^bRefers to the population ages 15–44 years.
 Sources: 1950 Census,³⁴ 1963 Census,³⁵ 1971 Census,³⁶ EDENIC-78,³⁷ ESDENIC-85 (unpublished data).

cent of the population were insured. By 1971 coverage of the population had increased to 7.5 percent and by 1978 to 8.4 percent. In 1980 under the Government of National Reconstruction, coverage reached 10.1 percent of the population.

The number of doctors and especially

nurses per head of population increased between 1974 to 1985. From 1970–74, there were 5.4 doctors and 2.3 nurses per 10,000 inhabitants. For the period 1975–79 there were 5.8 doctors and 2.6 nurses per 10,000 population and in the five years from 1980–84 there was an average of 6.0

doctors and 3.3 nurses per 10,000 population. The impact of the increased availability of health care professionals (together with dropping numbers of hospital beds per head of population) was reflected in rising per capita rates of hospital discharge and rapidly increasing numbers of outpatient consultations (especially emergency consultations).

Other Public Health Measures—

Nicaragua undoubtedly had low rates of access to plentiful clean water supplies and sanitation prior to 1974, but the situation has changed little since then. In 1981, the number of urban domiciliary connections was almost identical to that prior to the earthquake in 1972. Latrine construction by the Ministry of Health, which averaged 4,590 per year from 1974–78, was barely sufficient to keep up with the increase in the rural population.

The use of residual insecticides for the control of malaria decreased steadily in the late 1970s as the World Health Organization campaign for the elimination of malaria lost its momentum. The number of notified cases varied widely from one year to the next but showed no secular downward trend from 1972–82. The average annual reported number of laboratory confirmed cases was 15,386 from 1972–76 and 18,738 from 1977–81. A renewed effort was made to control malaria in 1981 by the administration of mass chemoprophylaxis but the impact was transient.

Discussion

From a variety of sources of infant mortality estimates, this paper has documented a rapid decline in infant mortality in Nicaragua which commenced in about 1974 and was still in progress in 1986. The rate of decline since 1974 is impressive, particularly considering that it occurred at a time when the mortality decline in most countries in Asia, Africa, and Latin America was slowing down.³³ The rate of improvement in life expectancy is similar to that experienced by either Costa Rica (at 0.70/year) and Kerala State (at 0.80/year) during their respective periods of rapid mortality decline, but is not as high as Sri Lanka's (at 1.7/year).³²

Much work on the determinants of reductions in child mortality has focused upon economic factors. It has often been difficult to separate the role of health and other social interventions from general economic progress, since changes have occurred in parallel. In Nicaragua, this was not the case as the sharp drop in child mortality took place at a time when the

TABLE 2—Average Number of Vaccines Administered per Child under the Age of Five

Years	DPT	Polio	BCG
1970-75	0.59	1.02	0.21
1976-80	0.48	1.24	0.17
1981-85	0.99	2.66	0.33

general living standards of the population, measured in terms of per capita national income, actually decreased.

Although there was some improvement in the nutritional status of Nicaraguan children between 1966 and 1988, this was probably more due to a reduced bur-

den of infectious illness than to increased food intake. The factors which led to a drop in the incidence, severity or duration of infection may be the same as those which brought about lower child mortality. It is difficult to follow breastfeeding practice over the last 20 years but it does seem that exclusive breastfeeding is still far from the norm for a variety of reasons.³⁴ While health education materials were concerned with promoting breastfeeding, the free milk provided by Ministry of Health programs before and after the insurrection may have encouraged mothers to abandon the practice.

The 1974 turning point in child mortality does not appear to have been brought about by a sudden increase in levels of female literacy, although this factor

may have contributed to more recent falls in child mortality. Similarly, most of the reduction in mortality due to diseases preventable by vaccination probably occurred some time in the early 1980s and does not coincide with the onset of the decline in child mortality.

The introduction of oral rehydration therapy (ORT) for the management of diarrhea did not occur until the middle of the period of rapidly declining mortality. The Ministry of Health's plan for 1976-80³⁵ does not even mention ORT, and it was not until 1980 that oral dehydration units were established in health centers and health posts.

The results of this investigation suggest that the availability of water supply and sanitation did not improve significantly from 1974-86. Any improvement in malaria control is unlikely to have been sufficiently great to account for the decline in infant mortality given that malaria is not a major cause of death in this age group in Nicaragua.³⁶

The most plausible explanation for the onset in 1974 of Nicaragua's rapid decline in infant mortality can be found in the changes in health services which started to take place at that time. The combined impact of declining per capita numbers of hospitals beds with increasing numbers of health care professionals meant greater availability of personnel to work in the understaffed clinics which had been built in the 1960s. In other words, there was in effect a sharp shift in resources away from hospitals and towards primary and secondary health care. Figure 5 shows how the number of hospital beds per health professional dropped sharply in 1972 and showed a tendency to decrease until at least 1984, parallel to the infant mortality decline.

The reason for this sudden shift in the nature of health care in Nicaragua is complex. The decreasing availability of hospital beds was due to a combination of the devastation resulting from the earthquake, the war, rapid population growth, and economic constraints to public spending. Training of health care professionals, on the other hand, surpassed the increase in population.

Political influences have no doubt also played a part in this situation. The decline and fall of Somoza has been dated from the 1972 earthquake^{34,37} and political turmoil has been the norm ever since. A mass popular movement grew up in the late 1970s culminating in the 1979 insurrection. Perhaps sensing that the ground was slipping out from beneath him, Somoza with United States aid began to make significant invest-

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ment in social programs. In these programs the government tried to target areas with major guerrilla activity.³⁴

In post-revolutionary Nicaragua, political factors have been equally important. The Sandinista National Liberation Front took power on a program in which health and education were key components.³⁵ In President Ortega's speech on the 10th anniversary of the Nicaraguan Revolution, reductions in rates of illiteracy and infant mortality were the first items held up as gains of the revolution.³⁶

Cultural factors may also have been important. Although tradition changes too slowly to explain a sudden reduction in mortality of the sort experienced by Nicaragua, certain cultural attributes facilitate rapid reductions in mortality. Primary health care programs can have little impact without appropriate patterns of health-seeking behavior. In Nicaragua, there exists what has been described as a pill culture.⁴⁰ People regard orthodox medicine and its providers (i.e. doctors and nurses) with high esteem. Manufactured pharmaceuticals, particularly when given by injection, are generally preferred to traditional herbal remedies although often both will be employed. Nicaraguans readily change treatments when a rapid improvement is not seen and are highly sensitive to the progress of illness in their children. As a result, when health services became more generally available in the 1970s and 1980s, the population quickly made use of them.

It is interesting to compare Nicaragua's period of rapid mortality decline with that of neighboring Costa Rica which also occurred during the early 1970s.^{41,42} Both countries had experienced a slow rate of improvement during the 1960s—a phenomenon common to many developing countries.⁴³ In Costa Rica, the drop in infant mortality was greater in rural areas than in urban areas, both in relative and absolute terms. An analysis of Costa Rica's recent decline in infant mortality also shows up the singular importance of primary health care.⁴²

Having reviewed the available data, it is possible to postulate the following scenario. In the late 1960s United States aid was used to pay for the construction of primary health care facilities throughout Nicaragua. In the 1970s, earthquake, war, rapid population growth and economic recession reduced the number of hospital beds per capita. At the same time there was an increase in the supply of nurses and doctors per head of population which made it possible to staff the recently built primary health care facilities. The net ef-

fect was an increase in the relative importance of primary and secondary health care vis a vis tertiary health care. The health care facilities provided gained rapid acceptance from the population which already had some cultural affinity for Western medicine.

The social reforms contributing to declining child mortality were made by an isolated and threatened dictatorship in response to the mobilization of improv-

ished sectors of society. They were continued and extended following the insurrection, as part of the political program of the Sandinista Government which replaced the dictatorship. In early 1990, a new government was elected which is committed to contraction of public expenditure. Monitoring the effects of any change in policy on child health and survival will provide an opportunity to ex-

APPENDIX—Sources of Infant Mortality Statistics in Nicaragua

A review was performed to identify the various sources of data on national child mortality rates in Nicaragua from 1960 to 1989. These are shown in Table A. A note of explanation is necessary about each of the data bases.

The 1971 Census

The last national census of Nicaragua took place on April 20, 1971. Since then, war and lack of funding have prevented the government from carrying out another population census. The 1971 census registered a total population of 1,878,000. The overall rate of omission is thought to be 6.3 percent but in 19 of the 126 municipalities there was an average omission rate of 32 percent and in a further 18 municipalities the rate was 22 percent.⁵ An experimental census was carried out in 1969 as a prelude to the 1971 census but its sample was small and unrepresentative of the entire population so the results are not presented here.⁴⁰

The National Demographic Survey of Nicaragua (EDENIC-78)

This was a survey carried out from 1977 to 1978 which included retrospective questions for indirect mortality estimation. It was a follow-up study in which it was intended to compare indirect estimations of mortality with prospective estimates derived from the household change technique. Unfortunately, during the 1979 insurrection all of the prospective data from this survey were lost, leaving only the retrospective questions for mortality estimation. Some of the retrospective data were also lost. The Atlantic Coast Departments of Zelaya and Rio San Juan were excluded from the sampling frame. Although the infant mortality rate in this area is probably higher than in the rest of Nicaragua, it is inhabited by only 8.6 percent of the population.

The Sociodemographic Survey of Nicaragua (ESDENIC-85)

This large household survey took place in 1985, aiming to generate up-to-date demographic and socioeconomic information for the whole country, given that the census planned for 1982 had been suspended. Technical assistance was provided by CELADE and the United Nations Department of Technical Cooperation for Development.⁴⁴

A pilot test in 535 homes was performed in September 1984 and definitive data collection commenced in July 1985. In contrast to EDENIC-78 which excluded the Atlantic Coast, the reference population of ESDENIC-85 covered the entire country. A two-stage cluster sample of 18,000 homes was chosen.

The Sentinel Sites Study

In 1986 the Ministry of Health (MINSA) in collaboration with consultants from UNICEF, established a set of 34 sentinel sites in three regions of the country.⁹ These were intended to provide accurate population-based data on morbidity, mortality, and health service utilization for planners and administrators. The sentinel sites were selected by regional teams on the grounds that they be representative of the health conditions of their region. Data were collected by household survey with indirect questions on child mortality.

The National System of Vital Statistics (SINEV)

In the 1960s, the civil register was administered by the Directorate General of Statistics and Censuses which was part of the Ministry of Economy. In 1970 the DGECE merged with the Department of Economic Studies of the Central Bank to form the Executive Office of Surveys and Censuses (OEDEC). Vital events were registered in the Offices of the Civil Register in each municipality. The data were published annually in the Statistical Yearbook. Coverage was estimated at 70 percent for births and 30 percent for deaths. Only 48 percent of registered deaths were certified by a doctor. The Ministry of Health was responsible for processing cause-specific mortality rates which were not published in Nicaragua but were sent to the World Health Organization.⁴⁵

When the new government took power in 1979, several changes were introduced to improve the registration of vital statistics but, despite these measures, serious deficiencies in death registration remain. In 1987, overall coverage was estimated at 47 percent,⁴⁶ but only about 34 percent of infant deaths are reported.¹¹ Birth registration is somewhat better; in 1983 coverage was calculated to be somewhere between 79.3 and 86.5 percent, varying from less than 60 percent in the rural population to about 95 percent in the urban population.⁴⁶

TABLE A—Sources of Infant Mortality Statistics in Nicaragua

Date	Data Source	Type of Data	No. Women Ages 15-34	Regional Coverage*
1971	National census ^{6,7}	Population census	256,907	100
1978	EDENIC-78 ⁸	Sample survey	6,237	91
1985	ESDENIC-85 ⁹	Sample survey	22,000 ^b	100
1986-88	Sentinel sites ¹⁰	Sentinel sites survey	9,615	54
1986-88	SINEVI ¹¹	Death registration	—	100
1988	SINEVI-88 ¹²	Birth registration	112,200 ^b	100

Source: References 6-12.

*The proportion of the inhabitants of the country included in the reference population.

^bApproximate only.

plore the validity of the explanations advanced in this paper. □

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