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Impact of Water Supply and Sanitation on Diarrheal Morbidity among Young Children in the Socioeconomic and Cultural Context of Rwanda (Africa)

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This project studied the frequency and intensity of water contamination at the source, during transportation, and at home to determine the causes of contamination and its impact on the health of children aged 0 to 5 years. The methods used were construction of the infrastructure for three sources of potable water, administration of a questionnaire about socioeconomic status and sanitation behavior, anthropometric measurement of children, and analysis of water and feces. The contamination, first thought to be only a function of rainfall, turned out to be a very complex phenomenon. Water in homes was contaminated (43.4%) with more than 1100 total coliforms/100 ml due to the use of unclean utensils to transport and store water. This socioeconomic and cultural problem should be addressed with health education about sanitation. The latrines (found in 43.8% of families) presented a double-edged problem. The extremely high population density reduced the surface area of land per family, which resulted in a severe nutritional deficit (15% of the children) affecting mainly young children, rendering them more susceptible to diarrhea (three episodes/child/year).

Key Words: water supply; sanitation; contamination; sociocultural context; diarrheal diseases.

INTRODUCTION

Background

The purpose of the study was twofold: first, to supply potable water, and second, to conduct a follow-up study on the diarrheal morbidity in a rural community in Butare, Rwanda. The overall goal was to determine the impact of water supply and sanitation on diarrheal morbidity among young children.

The authors acknowledge that this study was purely descriptive and do not attempt to statistically differentiate between sampling sites.

Rwanda is primarily an agricultural poor country, but since its independence from the Belgian colonial power in the early 1960s different governments have tried to build up a health care infrastructure aimed at controlling some of the fatal endemic diseases such as diarrheal diseases. The supply of clean water was seen as the most fundamental strategy for controlling diarrheal morbidity. In rural areas, more than half of the population has pit latrines (World Bank, 1988). However, children and some adults, due to a lack of education and their beliefs, still defecate in the fields. This contributes to the microbiological contamination of the rivers downstream in the rainy season. Diarrheal diseases and skin infections result from this contamination. Diarrheal diseases are the second cause of morbidity (20%) and mortality (25%) (Ministry of Health, 1993). Diarrheal diseases are the most important water-related diseases in Rwanda. They are responsible for vast amounts of morbidity in people of all ages, and, along with malnutrition, measles and malaria are very important in the very high child mortalities of those areas where between one-eighth and one-third of all children born may not reach their fifth birthday (Gasana, 1988). The diarrheal diseases are responsible for the majority of the economic losses ascribed to water-related diseases in many countries. They result from a range of infectious agents, but fall to a low incidence under good hygienic conditions. Rwanda is a small country (26,338 km²).
IMPACT OF WATER SUPPLY AND SANITATION ON DIARRHEA

(10,173 m²) for a population of 7.5 million (284.7 people per km² (458 people per mi²)), it has one of the highest population densities in the world (Ministry of Planning, 1992). According to Ntulivamunda (1988), in the first two years of life, infants and toddlers suffer an average of six to eight separate episodes of acute diarrheal disease per child per year.

Worldwide, about 51 million people died in 1993. Globally, the biggest killers were infectious and parasitic diseases, which accounted for nearly one-third of the total (WHO, 1993). In many cases, the most deadly diseases are also the most familiar, and as long as access to health care remains limited and sanitation is poor, they are likely to remain so (WHO, 1993). For example, although they are among the most highly manageable and curable of infectious diseases, diarrheal diseases, whether they were caused by a virus, a bacterium, or a parasite, claimed the lives of 3 million children in the developing world in 1993 (WHO, 1993). Most of these infectious and parasitic diseases are caused by the water-borne spread of bacteria, viruses, and parasites. Although infectious diseases account for only about 1 percent of deaths in developed countries, they are still the major killer in the developing world, accounting for a staggering 16.3 million deaths, or 41.5 percent of all deaths, in those nations in 1993 (WHO, 1993).

According to the United Nations (UN) (1993), 80% of all diseases and over one-third of deaths in developing countries are caused by the consumption of contaminated water. As much as one-tenth of every person’s productive time is sacrificed to water-related diseases (UN, 1993). An estimated 1.4 billion people still do not have access to safe drinking water and 2.9 billion do not have access to adequate sanitation (UN, 1997). According to the WRI (1998), this inadequate access to water and sanitation contributes to 2.5 million childhood deaths each year from diarrhea. The majority of pathogenic microorganisms come from animal and human feces, a result of unsanitary excreta disposal. Inadequate water supply plays an equally important role in the spread of disease. Most diseases that are water related may also be transmitted by person-to-person contact, aerosols, and food intake; thus, a reservoir of the bacteria is maintained in the people carrying the disease and a sick individual may contaminate water or food supplies, these by continuing disease transmission (WHO, 1993). Some people get infected without experiencing the disease symptoms, yet may still become carriers (Yassi, 2001).

In many areas of the world, fresh water is scarce and tremendous time and resources are devoted to obtaining it. All too often, that water is contaminated due to a lack of proper purification of water treatment and sanitation systems. This situation results in thousands of cases of water-related diseases every year in countries with inadequate clean water (Moore, 1999). The most common water-related diseases are diarrheal diseases, such as cholera, typhoid, paratyphoid, salmonella, giardiasis, and cryptosporidiosis. Diarrhea is defined as the passage of loose, liquid, or watery stools. These liquid stools are passed more than three times a day. The attack usually lasts 3 to 7 days, but may last up to 10–14 days.

In developing countries, diarrhea is almost universally infectious in origin. There are many infections which cause diarrhea. Among them are viruses such as rotavirus, adenovirus, Norwalk virus, etc. The rotavirus is the most important cause of diarrhea in infants and children. Nearly all children are infected at least once before the age of 2 years, and repeat infections are common. It spreads from person to person especially if personal hygiene is not good. An inadequate water supply, poor sanitation, overcrowding, and malnutrition are the main factors in the spread and severity of diarrheal diseases. Malnutrition and diarrhea are particularly closely linked: malnutrition increases the severity and duration of diarrhea, and diarrhea may cause malnutrition.

An adequate quantity of water, by itself, is not enough to safeguard health. An accessible and safe water supply, improved personal and domestic hygiene, and stronger community participation are the main ways to avoid water-borne diseases. But to be truly effective they must be accompanied by other measures, such as pollution control and proper drainage of surface water. Since environmental protection of fresh water sources is a basic step for ensuring a sustainable and clean water supply, this must always be an integral component of both environment and health programs.

Lack of access to clean water and proper sanitation is a major cause of diarrheal diseases, which in turn account for a large fraction of childhood morbidity and mortality. Apart from its direct role in averting transmission of diseases, clean water—adequate in quantity and conveniently located—is also an essential element for good personal hygiene and for keeping households and their immediate environment clean.

Diarrheal Morbidity in Developing Countries

Studies in Africa and Latin America indicate that a village child may have as many as 6 to 10 bouts of
diarrhea a year, each lasting an average of 3 days. In addition of being a pervasive killer diarrhea is also a significant contributor to malnourishment in those children who survive. Diarrhea acts, through increased malabsorption, reduced food intake caused by loss of appetite and food withdrawal, and fever, to deprive children of needed nourishment.

Unsanitary birth procedures and a mother’s dirty hands or breasts represent potential sources of contamination to the newborn infant, but these are slight compared to those encountered as the child grows and begins to drink water and eat weaning foods. The primary source of microbial contamination is human feces. Adults discharge disease-causing microbial agents in their feces, yet may not manifest any symptoms of disease. These agents may be transmitted to the child in a variety of ways, including (a) direct contact with feces through another person’s dirty hands, (b) direct contact through the child crawling on unclear surfaces, (c) indirectly through contaminated water, which is transmitted to the child as drinking water, bottle formula, and weaning foods, or (d) indirectly through hand transmission during the preparation of weaning foods. Perhaps the most prolific source of infection is weaning foods. As they sit in tropical heat, microbial growth increases phenomenally, and contact with large numbers of these agents produces diarrhea (AED, 1985).

In Rwanda, diarrheal diseases are the second cause of morbidity after malaria (146,457 cases = 20% of all the reported cases) and the second cause of mortality (376 deaths = 25% of all reported deaths) (Ministry of Health, 1993). Diarrheal diseases are predominately a problem of infants and children in Rwanda. More than 89% of children affected by diarrhea are 0 to 2 years of age; children from 6 to 11 months of age are the most affected which is probably due to the fact that in Rwanda the child begins weaning at that age (Gasana, 1988). A variety of infectious agents cause diarrhea through several pathogenic mechanisms. The most common agents are bacteria (shigella, vibrio cholera, and Escherichia coli), viruses (rotavirus), parasites (Giardia lamblia and Entamoeba histolytica). Human fecal material is deposited indiscriminately by small children or discriminately by adults. The occurrence of diarrheal diseases is negatively influenced by factors such as the availability of potable water, personal and domestic hygiene and nutritional status. The rationale of studies on water use and sanitation/ hygiene behavior has evolved through a long series of well-designed studies (Feachem, 1978, 1984; Briscoe et al., 1986; Cairncross, 1989, 1990; Esrey et al., 1990). The relevance of behavior patterns and procedures for studying them has also been explored. A number of reviews, outlines, and guidelines have been accumulated (Cairncross et al., 1980; Elmendorf and Buckles, 1980; Simpson-Hebert, 1983; White, 1983; WHO, 1983; Kochar, 1985; Srinivasan, 1990; Aziz and Islam, 1991; Boot and Cairncross, 1993). Studies have looked at the impact of having animals in the same household on the health of the young children. Case-control studies in Peru have demonstrated a high risk for Campylobacter diarrhea from the presence of chickens in the household (Grados et al., 1988). In another study, they demonstrated not only that the great majority (80 per cent) of chickens have Campylobacter in their cloaca (Black et al., 1989), but also that children of this age come in contact with chicken stools at least 3.5 times per day (Marquis et al., 1990). Further, Campylobacter survives for at least 24 hours in chicken feces located in the soil of these houses.

In many developing countries, there are two distinct diarrheal peaks each year, a cool-weather peak in which rotavirus is prominent, and a warm-weather peak in which E. coli, Shigella, and other bacterial pathogens are prominent (Briscoe et al., 1986). This feature can be used for the control of diarrheal diseases.

This study on the impact of water supply and sanitation on diarrheal morbidity in Huye, Butare, Rwanda (Africa) was launched after a great deal of work conducted on a number of sources had shown episodes of microbiological contamination. The results of the previous work showed that contamination of the water was a function of rainfall, but, surprisingly, the intensity of the contamination was very high in the dry season. The purposes of this study were to characterize more precisely the pattern of contamination of the sources (frequency and intensity) and to determine the cause by following the pattern of contamination of some representative sources over a relatively long period of time. It is well known that contamination of water at the source leads to contamination of drinking water at home. Therefore, it is important to verify whether the latter is a function of contamination of the source itself or of an external contamination. Contamination of the drinking water has an impact on the health of the population. Two criteria used to measure the impact are the development/growth of children and the frequency and cause of diarrheal diseases.

Episodes of the epidemics of bacillary dysenteriae were reported in the study area a year before the
start of this project. It was then decided to measure the influence of the water on this type of transmission. Indeed, it is known that water is a vector of various diseases and that the most sensitive subjects are young children aged 0 to 5 years. The development/growth of children with repeated episodes of diarrhea will be affected. That is why this was used a criterion for measuring the impact of diarrhea on the development/growth of children. Another important factor that intervenes in the development/growth of children is nutrition (in terms of quantity and quality).

Based on the above facts and study results, four representative sources in the study area were selected (Fig. 1) for the study of water contamination and its impact on the health of children.

Overall, the project had three phases. The first 3-month phase was the installation of basic infrastructures, along with baseline collection and analysis of water from the sources. The second phase was devoted to the analysis of feces and the administration of field survey questionnaires (15 months). The assessment of the physical development of the children was scheduled at the end of the first and second phases. The third phase was devoted to the analysis and publication of data (6 months).

Study Objectives

The objectives of this two-year cohort study were the following:

1. Supply basic infrastructures for clean water to the community,
2. Collect water samples for analysis at the source, during transportation, and at home,
3. Collect and analyze samples of feces from children aged 0 to 5 years,
4. Administer survey questionnaires about sanitation, and nutritional and health status of children, and
5. Determine the causes of water contamination and its impact on the health of children.

MATERIALS AND METHODS

Personnel

Ten part-time employees and their supervisor were hired for the duration of the project.

Population

The study population totaled of 3062 (Table 1) including 475 children aged 0 to 5 years (Table 2).
TABLE 1

Distribution of Population by Age Group

<table>
<thead>
<tr>
<th>Age group</th>
<th>Population</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-4</td>
<td>480</td>
<td>16.3</td>
</tr>
<tr>
<td>5-9</td>
<td>517</td>
<td>17.3</td>
</tr>
<tr>
<td>10-14</td>
<td>345</td>
<td>11.2</td>
</tr>
<tr>
<td>15-19</td>
<td>280</td>
<td>9.2</td>
</tr>
<tr>
<td>20-24</td>
<td>290</td>
<td>9.2</td>
</tr>
<tr>
<td>25-29</td>
<td>200</td>
<td>8.2</td>
</tr>
<tr>
<td>30-34</td>
<td>260</td>
<td>8.2</td>
</tr>
<tr>
<td>35-39</td>
<td>180</td>
<td>6.1</td>
</tr>
<tr>
<td>40-44</td>
<td>460</td>
<td>14.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3062</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

Study Design

Water Treatment Infrastructures

Basic infrastructures for clean water were supplied to the people of the community. First, a source of potable water was built using pipes, a water intake, a sedimentation tank, Katadyn filtration, and a storage tank with a communal tap (Site A). Second, a gravel–sand–charcoal filter was installed on an existing water spring (Site B). Given the flow rate of the source (2 liters per second), a T-shape construction was put into place to distribute the water into two parallel tanks containing gravel–sand–charcoal filters and then through a regular PVC pipe without a tap. Third, a protective fence was installed around an existing water spring (Site C). Fourth, another water spring was selected as a control source (Site D). Water supplies come from either the surface or below ground. A spring appears where a water table or some water-bearing strata discharges at the surface. Springs often are located in low areas and get contaminated from pollution sources at higher elevations. For instance, a spring located directly down-slope from an agricultural area or a latrine, or one that becomes muddy or has increased flow after a rain, is not a desirable water source. Special care must be taken when developing a spring. The overall objective is to collect the water flowing from the water table and at the same time prevent any surface water intrusion. This is achieved by various construction techniques, and they were used in this project.

Water Sampling

Water samples were collected from the four sources, transportation utensils, and storage utensils in homes. For Site A (the new source of potable water), water samples were collected from the following sampling stations: (i) A0, before the construction of the potable water source; (ii) A1, at the beginning of the new source of potable water; (iii) A2, at the outfall from the first tank of the new source of potable water; and (iv) A3, at the community tap fitted with Katadyn filter, where people get their water. The analysis of the water samples helped to characterize, in terms of frequency and intensity, the pattern of water contamination at the source, during transportation, and during storage in homes.

Collection of Samples of Feces

Samples of feces were collected from children and analyzed for microorganisms.

Field Surveys

Two types of surveys were conducted in this project. First, one-time questionnaires were administered to gather data on the census, socioeconomic status, nutritional status (using agricultural production, animal husbandry, and diets of children), water sanitation/hygiene practices, use of latrines, and food sanitation. Second, the ongoing survey questionnaires were administered to collect follow-up information on demographic, social, and agricultural changes and water transportation.

Anthropometric Measurements of Children

Measurements of the physical development of children were performed twice by a pediatrician at an interval of 14 months. This clinical examination consisted of measuring height, weight, brachial circumference, and skin wrinkles on the arms and back. The liver and the spleen were also inspected, along
with the presence of inflamed lymph nodes, edema, discoloration of skin and hair, and the descent of testicles. Follow-up on the vaccination schedules and new cases of diarrhea among children were also done.

Impact of Water Contamination on Children’s Health

The impact of water contamination on health was assessed among children aged 0 to 5 years by pediatricians who did regular medical checkups during their study period.

Water Analysis

Water samples from the sources (A, B, C, and D), during transportation, and homes were collected at a rate of two samples per weekday per source by the personnel of the project during a 3-month period. Samples were collected in 1000-ml sterilized bottles. All the collected samples were packed in an “igloo” (a plastic thermos-type insulated case) to maintain the temperature between 4°C (39°F) and 10°C (50°F). The bottles were lined with freezing pads to protect them from breakage and to maintain the cool temperature. They were then delivered to the Rwandan Medical School Laboratory within 2 h and kept in a refrigerator until processed within 2 h.

All the water samples were analyzed for total coliforms, fecal coliforms, and E. coli according to “Standard Methods for the Examination of Water and Wastewater” (APHA, 1989). The multiple-tube technique or the most probable number method was used with a dilution of 10 ml of water in three tubes, 1.0 ml of water in three tubes, and 0.1 ml of water in three tubes.

Analysis of Feces

Samples of feces from all the children at the four sites were collected, transported to the Rwandan Medical School Laboratory and analyzed for parasites and bacteria. The identification of parasites (ascaris, taenia, ankylostoma, Giardia, chilomastix, pentatrichomonas, Entamoeba coli, Entamoeba dysenteriae, Entamoeba hartmani) was carried out using a regular microscope (after dilution of feces in 1 ml of physiologic water). The detection of cryptosporidium was done using centrifugation, extraction with a mixture of formal-ether, and then coloration of the product of centrifugation with safranine and methylene blue.

With regard to the bacteriological analysis of feces, the laboratory used the coproculture, by which the diluted feces were cultured on three different media, namely xylose lactose deoxycholate agar, Salmonella-Shigella agar, and MacConkey agar. The identified colonies were recultured on Kligler medium and on urea–indole–Mobility and then incubated for 24 h at 37°C. Reculturing on Simmons citrate agar was also conducted. Finally, an antibiogram was carried out for each isolated pathogenic species in order to find out which treatment to provide the patient.

The identification of Campylobacter was made with Campylobacter agar kit Skirrow in an anaerobic cell at 43°C. After verification of the oxidase, the bacteria were colored on violet crystal.

Treatment of Diarrhea

Based on the results from the analysis of feces, a diagnosis was made for each case and a specific treatment was given to the child. The treatment was instituted by the medical doctors who were co-investigators in this project. They visited the children on a regular basis to provide them with the needed medications and, at the same time, checked on the field workers.

RESULTS

Water at the Source

Intensity of Contamination

Baseline data collected from all these sources showed concentrations ranging from 20 to 600 total coliforms/100 ml in the intervention sites (Sites A, B, and C) compared to concentrations ranging from 4 to more than 1100 total coliforms/100 ml in the control site (D). The concentrations of total coliforms ranged from 3 to 43 total coliforms/100 ml in the intervention sites compared to concentrations of 4 to more than 1100 total coliforms/100 ml in the control site. These concentrations indicated that factors (common to all the sources) are involved in the presence and proliferation of total coliforms; these factors may be related to problems of nutritional ecology.

For Site A (the new source of potable water), concentrations ranged from 3 and 5 total coliforms/1 ml in the intervention sites (Sites A, B, and C) compared to concentrations ranging from 4 to more than 1100 total coliforms/100 ml in the control site. These concentrations indicated that factors (common to all the sources) are involved in the presence and proliferation of total coliforms; these factors may be related to problems of nutritional ecology.

For Site B (the existing spring improved with a gravel–stand–charcoal filter), the results of the water analysis showed concentrations ranging from 4 to 9 total coliforms/100 ml. For Site C (the existing spring improved with an increase of the protected area), concentrations ranged from 9 to 43 total coliforms/100 ml. For Site D (the existing spring
that served as the control source), concentrations ranged from 4 to more than 1100 total coliforms/100 ml.

The distribution of fecal coliforms was similar to the distribution of total coliforms, with lower peaks for all of the sites except for Site A. These concentrations were very high compared to WHO drinking water standards. These standards do not allow any fecal coliform per 100 ml of drinking water, while they allow between 0 and 3 coliforms as a maximum number in occasional piped water samples only (Chapman and Kimstach, 1992).

The distribution of *E. coli* did not exhibit any high peak for any site.

**Frequency of Contamination**

The frequency of contamination was 88.6% for Station A0, meaning that this source was very contaminated (Fig. 2). The frequency of contamination was 14.6% for Station A3, showing the advantage of having a Katadyn filter as a means of water treatment. Station A0 seemed to be very polluted with more than 1100 total coliforms/100 ml. Station A1 showed concentrations ranging from 9 to 23 total coliforms/100 ml. Station A2 had an average of 5 total coliforms/100 ml, and Station A3 an average of 3.

The results of water obtained from the existing spring that was improved with a gravel-sand-charcoal filter at Site B showed that the filter did not work properly. The site turned out to be heavily contaminated. Its pollution could be explained by various factors, such as high population density at this site (1433 people/km² living in 86 households).

Site A had the same type of soil in terms of transfer of bacteria into the water and had 58.8% as the frequency of pollution, possibly because it had a lower population density.

Although site C was not very contaminated before the installation of the area of protection, there was an observed reduction in pollution from 56.8% before installation (based on a sample size of 44), to 47.1% after installation (based on a sample size of 210).

For Site D, many peaks were present in the dry season, which meant that the pollution was not a function of rainfall. In fact, the site had the same soil as C, but it was less polluted. Other factors such as density (1231 people/km²) did not contribute to the contamination of the source, since homes were built farther from the source than at other sites. Its source of contamination was probably groundwater, as opposed to superficial water. There may have been a leak between the groundwater and the surface water, possibly through family latrines.

**Influence of the Duration of Rainfall on the Contamination of Water**

After 5 consecutive days of both dry weather and rain, there was a consistent pattern of contamination. Contamination did, however, increase during days of rainfall (Fig. 3).

**Other Factors Influencing Contamination**

The project studied the influence of other factors, such as the type of water supply, the topography of valleys, and the filtration of the subsoil, using physicochemical measurements such as flow rate, pH, conductivity, cations, suspended soils, and temperature. However, the influence of these factors did not appear to be highly significant.

**Use of Artificial Systems**

The installation of simple artificial systems in order to improve the quality of water was effective only with the Katadyn filter, even though there were some technical problems with it.

**FIG. 2.** Frequencies (in percentages) of Water Sample Contamination by Site.

**FIG. 3.** Frequencies (in percentages) of Water Sample Contamination by Site and Rainfall, Butare, Rwanda.
Factors Influencing Water Contamination in Homes

Conditions of Transportation

Overall, of 1152 water samples analyzed, all but 57 (4.9%) showed total coliforms. Moreover, 610 water samples (53%) had concentrations of more than 1100 total coliforms/100 ml of water. These high frequencies indicated an additional contamination of the water between the source and the home. The frequency of contamination was 92.5% for fecal coliforms and 89.2% for E. coli, i.e., values very high and close to the ones for total coliforms. The interpretation of Fig. 4 shows a behavior grossly similar for all four sites, with however, some differences. The least contaminated was site A, followed by site B, site D, and finally site C.

Conditions of Storage

Table 3 shows that there was no difference between the four sites regarding the storage utensils and the mixing of fresh and stored water. On the other hand, the homes with less pollution had storage that were cleaned more often. The contamination of water by the storage utensils could be seen by the naked eye in half of the cases (the water appeared dirty); for the second half a laboratory analysis was done which provided the distribution of contaminants during storage (Table 4).

Sociocultural Factors

Quality of Housing

Overall, 70.8% of the homes had tiled roofs, 19.5% thatched roofs, and 9.6% sheet iron roofs. Considered the poorest (26.2%), site C had the highest number of thatched roofs (with one small house and a small yard).

Occupation and Education

The profession held by the head of the family was, in most cases, agricultural (77.1%), with 19.4% salaried employees and only 2.9% businessmen. Site A had the lowest percentage of salaried people (9.2%), along with an absence of businesswomen. For site D, there were no businessmen. The profession held by the mother was agricultural (97.2%). The percentage of mothers in agriculture was lower for site B (91.8%) due to the presence of businesswomen. The nature of the professions of the families indicated an area essentially rural, involved in agricultural production and animal husbandry.

The level of education of the parents showed an average of 2.8 years for mothers and 2.6 years for the fathers; however, these numbers did not reflect the fact that 37.6% of the mothers and 36.8% of the fathers had never been in school.

Household Equipment

The living standard of the population was measured by the number of items of so-called “luxury”, a radio, a bicycle, a motorcycle, or a car. Site D had the most items. Site B had some rich families, with motorcycles or cars, and site C appeared to be the poorest with a low percentage of bicycles. The radio

TABLE 3

<table>
<thead>
<tr>
<th>Storage of Water at Home</th>
<th>Presence (N=3062)</th>
<th>Frequent cleaning (%)</th>
<th>Rare cleaning (%)</th>
<th>No mixing of water (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>41.3</td>
<td>49.9</td>
<td>43.6</td>
<td>66.3</td>
</tr>
<tr>
<td>Those with less pollution</td>
<td>40.3</td>
<td>59.3</td>
<td>39</td>
<td>69.3</td>
</tr>
</tbody>
</table>

TABLE 4

<table>
<thead>
<tr>
<th>Influence of Storage on Water Contamination (N=3062)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicators (per 100 ml)</td>
</tr>
<tr>
<td>-------------------------</td>
</tr>
<tr>
<td>Total coliforms</td>
</tr>
<tr>
<td>Fecal coliforms</td>
</tr>
<tr>
<td>E. coli</td>
</tr>
</tbody>
</table>

Note. All values are percentages. D1, before mixing of water at home; D2, 15 min after mixing of water at home.
Animal Husbandry

Site A had the most animals. These included chickens, pigs, goats, rabbits, and cows. Site B had a number of animals lower than average, with, however, more cows. Site C had the average, with a predominance of pigs and chickens. On site D, people had less goats and more chickens and cows, but no rabbits. Most of the time, the animals shared the house with the people during the night; this had tremendous consequences in terms of sanitation in the house, especially with the chickens, which are known to carry Campylobacter.

Agriculture

The average surface area of a parcel per family was 65 ares (1.4 acres), which had important repercussions on people's nutritional status and living conditions.

Socioeconomic Score

The population was classified into the following three categories: (1) 65% of the households were poor, with a score from 3 to 16; (2) 20% were middle class with a score from 17 to 35; and (3) 15% were rich, with a score from 37. In this study, the majority of the people were poor.

Children's Diets

Number of meals per day. The average number of meals per day was 3.3 for site A, 2.4 for site B, 2.9 for site C, and 3.0 for site D. The low average number of meals observed for site B was related to the highest number of families in which children would get only one meal and few snacks for the rest of the day.

Food served during the weaning period. There were tremendous variations from one site to another, with important differences in terms of the priority of food items. Parents of site D seemed to give more fruits, while those of Site A gave less fruits.

Food Provided in Case Diarrhea

There were variations in terms of food priority from one site to another. However, in all the sites rice and watery rice was the main treatment for diarrhea (Table 5). Site D was characterized by a good adjustment to the problem of diarrhea in terms of the variety food types, this was also true for site C. Those at Site B simply increased the number of meals in cases of diarrhea. Those at Site A did not change the types of food much in cases of diarrhea.

Factors Influencing Sanitation

Latrines

For sites A and B, 12.3% of the families did not have latrines compared to 18% for sites C and D. There were no latrines in 43.8% of the poor families. These families defecated in their neighbors' latrines in 56% of the cases or used a hole dug in the soil. Overall, few latrines were covered; therefore, they were easily reached by external elements (rain and flies), and their maintenance was rated as poor.

There were fresh feces (or less than 24 h) scattered in 32% of the latrines of sites A and B, in 19% of the latrines of site C, and in 24.2% of the latrines of site D. In fact, only 2.5% of the children, for all the sites, used a hole in the soil. The majority of the children (91.5%) defecated in the front yard of the house, even if some used the latrines sometimes.

Personal Sanitation

The first-born in the family took his/her bath every day, the fourth child every 2 days, the fathers every 3 days on average and the mothers a little less often. There was no difference between the sites or change over time.

Food-Related Sanitation

Overall, the hygienic conditions related to food were not satisfactory, except for the wealthy families who could afford to change used utensils regularly.
TABLE 6

<table>
<thead>
<tr>
<th>Site</th>
<th>No. children</th>
<th>Average age (months)</th>
<th>Z score, average weight</th>
<th>Z score, average height</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>80</td>
<td>31</td>
<td>-1.65</td>
<td>-2.01</td>
</tr>
<tr>
<td>B</td>
<td>117</td>
<td>29</td>
<td>-1.44</td>
<td>-1.82</td>
</tr>
<tr>
<td>C</td>
<td>191</td>
<td>28</td>
<td>-1.82</td>
<td>-2.18</td>
</tr>
<tr>
<td>D</td>
<td>53</td>
<td>30</td>
<td>-1.80</td>
<td>-2.00</td>
</tr>
<tr>
<td>Total</td>
<td>441</td>
<td>29</td>
<td>-1.66</td>
<td>-2.03</td>
</tr>
</tbody>
</table>

There was a lack of equipment, leading to an exchange between neighbors and less frequent cleaning of utensils. There was also a serious lack of protection of cooked food.

Factors Influencing the Health Status of Children

Anthropometric Indices

The sample represented in Table 6 corresponds to the children examined twice. The numbers obtained correspond to the deviation from the mean of malnutrition, on the basis of the scale from NCHS (U.S. National Center for Health Statistics). A negative deviation of -2 shows severe malnutrition. One significant deviation (P < 0.05) is observed between sites B and C for weight.

Vaccination Coverage

Table 7 shows that vaccination coverage was good and similar for all sites. This indicated an effective

TABLE 7

<table>
<thead>
<tr>
<th>Type of vaccine</th>
<th>Site A (N = 80)</th>
<th>Site B (N = 117)</th>
<th>Site C (N = 191)</th>
<th>Site D (N = 53)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.C.G. (TB)</td>
<td>88</td>
<td>79</td>
<td>88</td>
<td>91</td>
</tr>
<tr>
<td>Poliomyelitis</td>
<td>1</td>
<td>86</td>
<td>78</td>
<td>84</td>
</tr>
<tr>
<td>2</td>
<td>77</td>
<td>68</td>
<td>75</td>
<td>81</td>
</tr>
<tr>
<td>3</td>
<td>44</td>
<td>41</td>
<td>47</td>
<td>31</td>
</tr>
<tr>
<td>D.T. Coq.*</td>
<td>1</td>
<td>88</td>
<td>78</td>
<td>87</td>
</tr>
<tr>
<td>2</td>
<td>85</td>
<td>73</td>
<td>84</td>
<td>87</td>
</tr>
<tr>
<td>3</td>
<td>77</td>
<td>68</td>
<td>73</td>
<td>81</td>
</tr>
<tr>
<td>4</td>
<td>43</td>
<td>39</td>
<td>44</td>
<td>31</td>
</tr>
<tr>
<td>Measles</td>
<td>73</td>
<td>63</td>
<td>68</td>
<td>77</td>
</tr>
</tbody>
</table>

*D.T. Coq., diptheria + tetanus + coqueluche (= pertussis).

There were a lack of equipment, leading to an exchange between neighbors and less frequent cleaning of utensils. There was also a serious lack of protection of cooked food.

TABLE 8

<table>
<thead>
<tr>
<th>Type of infection</th>
<th>Clinical examination (%)</th>
<th>Site A (N = 200)</th>
<th>Site B (N = 220)</th>
<th>Site C (N = 239)</th>
<th>Site D (N = 180)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impetigo</td>
<td>First</td>
<td>21.5</td>
<td>6.9</td>
<td>2.6</td>
<td>9.8</td>
</tr>
<tr>
<td>furuncle, folliculitis</td>
<td></td>
<td>14.1</td>
<td>13.5</td>
<td>3.7</td>
<td>6.4</td>
</tr>
<tr>
<td>Impetigo, Second</td>
<td>First</td>
<td>3.1</td>
<td>1.7</td>
<td>4.9</td>
<td></td>
</tr>
<tr>
<td>furuncle, folliculitis</td>
<td></td>
<td>22.2</td>
<td>6.3</td>
<td>16.6</td>
<td>14.9</td>
</tr>
<tr>
<td>Scabies First</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scabies Second</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

management of prevention by the health centers of the region, whose network was well developed.

Clinical Inspection

With regard to impetigo, furuncle, and folliculitis, the highest rate was observed in Site A, Site C being the least affected (Table 8). The signs of a fully blown malnutrition appeared to be very frequent (one-third of the children are malnourished nationwide) and varied from site to site. Compared with the results of the anthropometric measurements, they suggested that the problem of malnutrition is chronic in these sites (Table 9).

Number of Cases of Diarrhea

For a 1-year period, the number of cases of diarrheas was three-child/year (Table 10).

Causes of Diarrhea

The cause of diarrhea could not be attributed to parasitic worms; the ascaris found was obviously eliminated as a cause of diarrhea. The incidence of hookworm, Hymenolepis diminuta, oxyuriosis, trichocephalosis, and taenia was low (Table 11). The viruses were not studied because of a lack of

TABLE 9

<table>
<thead>
<tr>
<th>Type of malnutrition</th>
<th>Site A</th>
<th>Site B</th>
<th>Site C</th>
<th>Site D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marasmus</td>
<td>10</td>
<td>13</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>Kwashiorkor</td>
<td>11</td>
<td>15</td>
<td>14</td>
<td>15</td>
</tr>
</tbody>
</table>
GASANA ET AL.

TABLE 10
Average Number of Cases of Diarrhea by Site

<table>
<thead>
<tr>
<th>Site</th>
<th>Average number of cases of diarrhea/child year</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
</tr>
<tr>
<td>C</td>
<td>4</td>
</tr>
<tr>
<td>D</td>
<td>3</td>
</tr>
</tbody>
</table>

equipment able to detecting them. In Rwanda, about 40% of the diarrheal diseases were caused by rotavirus for children between 0 and 35 months (Ntilivamunda, 1988).

DISCUSSION

The overall picture suggested by recent studies focusing on diarrheal morbidity is not very different from that offered by the older ones. Most of the studies suggest that access to water, increased water usage, and improvements in hygiene may have a greater impact on diarrhea than quality and excreta disposal (Cairncross, 1994). In this study, population density and nutritional deficit significantly contributed to childhood diarrheal morbidity. Any project dealing with the impact of water supply and sanitation on diarrheal morbidity must look at ways of controlling the population density and nutritional deficit before any appreciable decrease in diarrheal morbidity can be seen. Therefore, the prevalence of diarrheal morbidity can be diminished using a four-pronged strategy, including (1) water supply, (2) excreta disposal, (3) sanitation/hygiene, and (4) improvement of socioeconomic status.

Domestic unavailability of a water supply in Rwanda and other developing countries has often led to improper use of supplied or other unsafe sources of water such as rivers, springs, dams, and bore holes. In this study, water was generally obtained from communal taps, public standpipes, and springs and stored in various forms of containers. Tests for microbiological indicators indicated limited instances of fecal and other forms of microbiological contamination in sections of the water supply network.

Indications that the network in this area could intermittently be subjected to pollution from unknown sources were also found. Tests on the bulk water supply from the source to the consumer water network indicated no fecal contamination in the bulk supply. In general, the supply quality tested indicated no risk to consumers. However, the unsanitary condition of containers as well as the manner of storing and handling the containerized water led to contamination of water supplies. By implication, the system of water supply through public standpipes was conductive to conditions that could lead to contamination of stored water supplies in households within the target consumer group. The association found between type of container and water contamination from source to storage is consistent with findings of other studies in developing countries (Peachem et al., 1978; Lindskog and Lindskog, 1988; Mertens et al., 1990; Verweij et al., 1991; Mintz et al., 1995).

The present study supports Van derAliche and Briscoe’s (1995) proposed theory that by improving water quality alone, no impact on diarrhea would be seen in children living in highly contaminated neighborhoods. The critical role of additional factors such as improved hygiene and health-related knowledge and practices, in reducing the incidence of diarrhea is exemplified in a recent review by the U.S. Agency for International Development (1992). Most of the intervention studies included in this

TABLE 11
Number of Cases of Diarrheal Diseases by Types of Microorganisms (Excluding Viruses)

<table>
<thead>
<tr>
<th>Types of microorganisms</th>
<th>No. cases</th>
<th>No. controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parasitic worms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ascaris</td>
<td>49 (21%)</td>
<td>19 (23%)</td>
</tr>
<tr>
<td>Hookworm</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Hymenolepis diminuta</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Oxyuriasis</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Trichuriasis</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Taenia</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Parasitic protozoa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entamoeba coli</td>
<td>16 (7%)</td>
<td>5</td>
</tr>
<tr>
<td>Giardia lamblia</td>
<td>25 cysts (14%)</td>
<td>15 cysts (3%)</td>
</tr>
<tr>
<td>Entamoeba hartmannii 7</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Entamoeba histolytica</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Chilomastis meesl</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Pentatrichomonas</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>hominis</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Other parasites</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fungus (blastocystis)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>hominis</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cryptosporidium</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Bacteria</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shigella flexneri E.</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>coli</td>
<td>10 (11.9%)</td>
<td>8 (8.8%)</td>
</tr>
<tr>
<td>Campylobacter</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>Leucocytes</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Yeast</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Red blood cells</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>
review were aimed at improving quality or availability of water or disposal of excreta. The review showed that the effects of these improvements are large; median reductions from 22 percent for diarrhea to 76 percent for guinea worm. It is recommended that these additional factors be considered when making policy guidelines for the provision of water in developing countries. With regard to water supply and sanitation programs, the main activities should include installing neighborhood committees, imparting hygiene messages through health centers, radio and local forum theater, school sanitation promotion and latrine construction, action-research, advocacy of experiences, institutional adjustment, and capacity building. Target practices are hand washing with soap and disposal of stools in potties and latrines. The primary target audiences are mothers of children under 3, maids and child caretakers, and children of primary school age. Factors considered to motivate behavior change are, for mothers/caretakers, that hygiene is a social virtue and, for children, that hygiene helps to avoid diarrhea (UNICEF, 1998).

CONCLUSIONS

The results of this study showed that using an artificial drinking water treatment system decreased the concentration of coliforms from 4 to 1100 total coliforms per 100/ml to 3–5 total coliforms per 100/ml. The density of the population determined the frequency of contamination (Site B with 1433 people/km2 living in 86 households had the highest contamination). Rainfall played a contributory role to the contamination of water.

Personal sanitation was another determining factor for the increase in contamination (hygiene practices, storage of the water, latrines (43.8% of population had no latrines)). Socioeconomic status played a contributory role to the poor standard of living (substandard housing, agricultural subsistence, and a low educational level of 2.8 years on average). Poor nutritional status increased the susceptibility to diarrheal diseases (on average, three episodes per child per year). Malnutrition increases the severity and duration of diarrhea, and diarrhea may cause malnutrition.

Water provision is seen by a large sector of people as the most fundamental means of survival. However, with regard to health challenges facing the developing countries, sanitation is an area that is not being adequately addressed, primarily because of a lack of demand. This problem is being exacerbated by some development organizations that provide “free” sanitation without people appreciating the need for sanitation.

The control of diarrheal diseases must be a comprehensive program including the water supply, excreta disposal, health education, and improvement of the standard of living. There is no best way to achieve health improvements, except that it must be by people themselves. Interventions in water supply and sanitation infrastructure, together with hygiene education and the extension of primary health care services in Rwanda, need to be implemented within an integrated multidisciplinary framework. This should result in a significant reduction in the incidence of diarrheal disease and its severity (including death), which may be associated with a reallocation of health care resources to other pressing health and social needs.

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