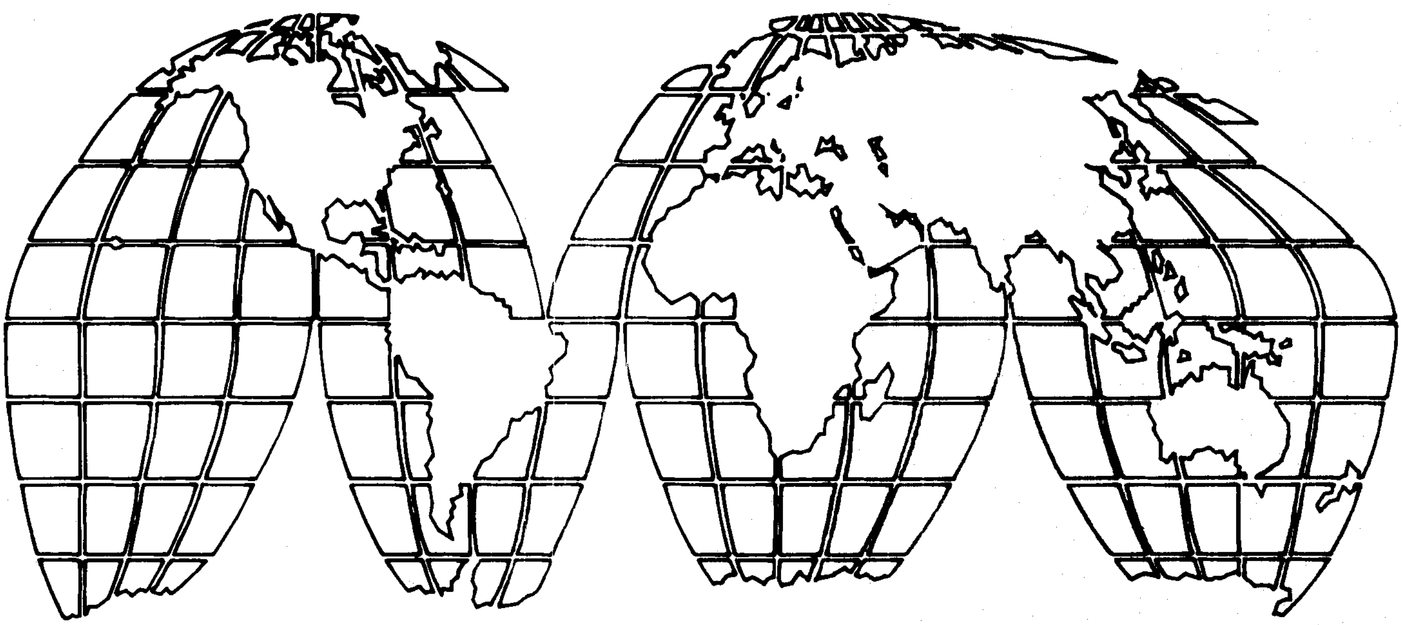
PN-AAJ-007

A.I.D. Evaluation Special Study No. 2

Water Supply and Diarrhea: Guatemala Revisited



August 1980
Agency for International Development

A.I.D. EVALUATION PUBLICATIONS

PROGRAM EVALUATION DISCUSSION PAPERS

No. 1: Reaching the Rural Poor: Indigenous Health Practitioners Are There Already (March 1979)
No. 2: New Directions Rural Roads (March 1979)
No. 3: Rural Electrification: Linkages and Justifications (April 1979)
No. 4: Policy Directions for Rural Water Supply in Developing Countries (April 1979)
No. 5: Study of Family Planning Program Effectiveness (April 1979)
No. 6: The Sociology of Pastoralism and African Livestock Development (May 1979)
No. 7: Socio-Economic and Environmental Impacts of Low-Volume Rural Roads--A Review of the Literature (February 1980)
No. 8: Assessing the Impact of Development Projects on Women (May 1980)

EVALUATION REPORTS

PROGRAM EVALUATIONS

No. 1: Family Planning Program Effectiveness: Report of a Workshop (December 1979)
No. 2: A.I.D.'s Role in Indonesian Family Planning: A Case Study With General Lessons for Foreign Assistance (December 1979)
No. 3: Third Evaluation of the Thailand National Family Planning Program (February 1980)
No. 4: The Workshop on Pastoralism and African Livestock Development (June 1980)

PROJECT IMPACT EVALUATIONS

No. 1: Colombia: Small Farmer Market Access (December 1979)
No. 2: Kitale Maize: The Limits of Success (May 1980)
No. 3: The Potable Water Project in Rural Thailand (May 1980)
No. 4: Philippine Small Scale Irrigation (May 1980)
No. 5: Kenya Rural Water Supply: Program, Progress, Prospects (June 1980)
No. 6: Impact of Rural Roads in Liberia (June 1980)
No. 7: Effectiveness and Impact of the CARE/Sierra Leone Rural Penetration Roads Projects (June 1980)
No. 8: Morocco: Food Aid and Nutrition Education (August 1980)

SPECIAL STUDIES

No. 1: The Socio-Economic Context of Fuelwood Use in Small Rural Communities (August 1980)
No. 2: Water Supply and Diarrhea: Guatemala Revisited (August 1980)
No. 3: Afghanistan Basic Village Health (Forthcoming)

PROGRAM DESIGN AND EVALUATION METHODS

Manager's Guide to Data Collection (November 1979)

WATER SUPPLY AND DIARRHEA: GUATEMALA REVISITED

A.I.D. Evaluation Special Study No. 2

BY

Daniel Dworkin

Agency for International Development
Bureau for Program and Policy Coordination
Office of Evaluation
Studies Division

and

Judith Dworkin

Department of Hydrology and Water Resources
University of Arizona

Office of Evaluation
Bureau for Program and Policy Coordination
U.S. Agency for International Development

August 1980

CONTENTS

EXECUTIVE SUMMARY

For the first time we can demonstrate in a well-controlled study a reduction of diarrhea associated with the improvement of water supply in a rural community. Diarrhea declined substantially when an improved source of water was piped to the patios of most homes in a Guatemalan village. All age groups except infants less than a year and adults over 45 showed statistically significant differences in rates when compared to a control community. Children between one and seven years old, who accounted for more than half the cases of diarrhea in the village, were the major beneficiaries.

Percentage Decrease in Diarrhea One to Seven Age Group

Successive Six Month Periods:	(1)Rainy	(2)Dry	(3)Rainy	(4)Dry	(5)Rainy	(6)Dry	(7)Rainy
Percentage D[illegible]	+4	-32	-16	-48	-22	-41	-24

W [illegible] ficient to reduce the diarrhea. Education in sanitary practices and a program to build latrines were successful in changing attitudes and behavior, but had little, if any, association with diarrhea rates.

Water Quantity - Water Quality

The evidence seems to indicate that it was water quantity that was responsible for the improved health of the community rather than water quality. This is based on the following data. The amount of water used at the home was nearly three times greater in the experimental community than in the control village. Water quality, however, while good at the tap, deteriorated in the transfer from the tap to the domestic containers. By laboratory analysis, half the samples from domestic containers had fecal coliform bacteria and three quarters had some coliform bacteria.

The Study

The study was carried out in two communities in Guatemala. They were selected to be similar in population, environment, and health characteristics.[1] One was provided with a piped supply that served most of the community. The other, which obtains water from shallow wells and a river, served as a control. The purpose of the control community was to account for variations in health that would have happened without the improved source of supply. Halfway through the project, a health program to alter sanitary behavior and to encourage latrine construction was instituted.

---

[1] The study was funded by the AID Bureau of Development Support.

The study met all the criteria that were considered necessary to determine the effect of water on health by a World Bank expert panel. For 40 months, from May 1973 to August 1976, each household in both communities was surveyed. Data on health, nutrition, environmental sanitation and water use were gathered.

Previous Findings

A previous analysis of the data did not find any significant reduction in diarrhea associated with the new water supply. The difference between the previous findings and these conclusions results from the methods used in the data analyses. We have compared rates of diarrhea in groups from each community. The groups were segregated by age, sex, season, and family size. A comparison between the same group in the experimental community and the group in the control community, indicated that in all cases the differences in rates of diarrhea were statistically significant.

(The previously published analyses used a regression equation containing 63 variables to determine the association of water, family size, time, environmental conditions and other variables with diarrhea. Using such a method, the study found significant reductions in one age group. Because it was not matched by reductions in other groups of different ages the study regarded this as a possible "random variability".)

We consider the use of contingency tables and calculation of Chi Square test of significance the more appropriate statistical test for data from two communities selected as a matched sample. The Bureau of the Census concurs. They carried out most of the statistical analysis and agreed with our findings.[2]

Lessons Learned

Developers can now have far more confidence that improved, reliable supplies have a signficant health benefit. This finding is of major importance. The value of clorination and health education will be assessed in a subsequent article.

---

[2]Joseph Quinn, Survey Statistician of the International Statistical Program, Bureau of the Census, advised on the methodology and prepared the analysis on which the paper is based.

Abstract

Improved access to a chlorinated water supply from a protected spring in an experimental community was accompanied by a significant reduction in the incidence of diarrhea among villagers of all age groups with the exception of those less than one and over forty-five years old when compared to the same age group in a control village. Those most affected were the age group from one to seven who accounted for more than half the cases in both the experimental and control community. The decrease in diarrhea was related to the amount of water used and to the seasonal variation in rainfall. The study conducted for 42 months had previously reported no significant reduction in diarrhea for any age group in the experimental community.

BACKGROUND

A recent study on the health effects of improved water supply, health education and improvements in excreta disposal was conducted by the University of North Carolina at Chapel Hill and the Institute of Nutrition of Central America and Panama. The study, the Food Wastage/Sanitation Cost-Benefit Methodology Project, was carried out in two villages in the rural lowlands of Guatemala. The purpose was to determine the impact of a number of improvements on the health of the villagers. These improvements were a filtered chlorinated source of water to the patios of most houses, a health education campaign designed to alter sanitary practices and a community development effort to encourage building of latrines. The results were reported to AID in three volumes, Results of the Field Studies, February 25, 1978; Assessment and Policy Implications, July 31, 1978; and Methodology Report, March 31, 1978. Articles, "Field Studies on Water Sanitation and Health Education in Relation in Central America," by Shiffman *et al*., (1978) and "The Potential Effect of Water on Gastrointestinal Infections Prevalent in Developing Countries," by Schneider *et al*., (1978) were published independently.

A number of indicators were used to assess the impact of the project. These included the waste of nutrition through intestinal mal-absorption, diarrhea, respiratory disease, skin infections and a number of infectious diseases. This paper will focus on only one of the indicators, diarrhea. The study had reported no decrease in diarrhea as a result of the improved supply, but had documented a significant decrease in skin disease.

The United States Agency for International Development (AID) funded the study as a part of a continuing interest in determining the impact of various interventions on the health of the recipients. There is extensive evidence that diseases are transmitted by contaminated supplies but little unequivocal evidence that improved supplies have any impact on diarrhea in the community served. A number of studies have examined the impact of water supplies on diarrhea. Some of those most frequently cited are Watt _et al_., 1953; Hardy and Watt, 1948; Hollister _et al_., 1955; Levine _et al_., 1976; Schliessmann _et al_., 1958; Moore _et al_., 1966; Feacham _et al_., 1978. There is some evidence, which a recent study considers well documented, that reduction of disease requires connections within the house (Walsh and Warren, 1979).

In examining the body of evidence available up to 1976, an expert panel convened by the International Bank for Reconstruction and Development (IBRD) concluded that the past investigations were "faulty" in precision of measurement, in adequacy of base data, and in accuracy of findings" (1976, p.6.). Kawata (1978) also reviewed the past studies that had found no relationship of water on health status and found them to be faulty. In a similar review White, Bradley and White concluded "...there is little doubt that for precise conclusions of the health effects of water a planned experimental installation of water and sanitation is needed" (1972). The AID study in Guatemala was designed to provide the necessary precision.

Study Design

The principle of the study is simple: select two communities that are similar. Provide one of them, the experimental community, with an improved source of water supply. The other community would serve as a control. Halfway through the study provide a health education component for the experimental community. Any changes in the experimental community relative to the control community could then be ascribed either to water alone or water and the health program.

The objective of using a control community was "to track internal and external changes in health status, behavior and the community environment which presumably would have occurred even in the absence of any large scale intercession. In addition to expected changes over time, the mere presence and activities of the study staff could have stimulated some of the changes". (Results of the Field Studies, p.4.) Although the objectives of using the control community were clearly articulated in the study plan, they were not integrated into the data analysis as a method of controlling for changes in health status of the experimental community that might have occurred without the water project. Data from both the experimental and control community were analyzed independently and the results compared at the conclusion of the study.

Community Selection

Communities selected were comparable in size and in age and sex distribution (Table 1). Guanagazapa, the experimental com-

Table 1

Village Population Experimental and Control Community
At Beginning and End of Project

Group	Experimental Community Population		Control Community Population	
	Beginning	End	Beginning	End
0-1 years	45	42	37	52
1-7 years	203	218	170	199
7 + years	769	.837	656	755
Number of males	528	566	469	535
Number of females	489	531	394	471
Number of families	202	238	199	210
TOTAL Population	1,017	1,097	863	1,006

Source: Final Report to the Agency for International Development, Department of State, Results of the Field Studies, University of North Carolina at Chapel Hill and Institute of Nutrition of Central America and Panama, (February 1978) pp. 4, Table II.

Table 2

Bacteriological Water Quality Experimental
and Control Communities
(Laboratory Analyses)

	Experimental Community		Control Community	
	Source	Domestic Container	Source	Domestic Container
Most Probable No.				
Total Coliform	611	423	1840	2767
Fecal Coliform	484	393	1205	1304
Range				
Total Coliform	0-5420	0-1609	23-2780	1300-9180
Fecal Coliform	0-5420	0-2400	5-2400	79-2400
Percent Satisfactory				
Total Coliform	42	25	0	0
Fecal Coliform	75	50	0	0

Source: Final Report to the Agency for International Development, Department of State, Results of the Field Studies, University of North Carolina at Chapel Hill and Institute of Nutrition of Central America and Panama (February 1978) pp. 26, Table IV-4.

Table 3

Months of Data Collection and Designation of Seasons

Type of Season	Month	Year 1973-1974	1974-1975	1975-1976	1976
		Season No.	Season No.	Season No.	Season No.
Rainy (R)	May	1	3	5	7
	June	1	3	5	7
	July	1	3	5	7
	Aug	1	3	5	7
	Sep	1	3	5	----
	Oct	----	3	5	----
Dry (D)	Nov	2	4	6	----
	Dec	----	----	----	----
	Jan	2	4	6	----
	Feb	----	4	6	----
	Mar	2	4	6	----
	Apr	2	4	6	----

NOTE: A dash (----) indicates that no morbidity data were collected in the indicated month.

Source: Final Report to the Agency for International Development, Department of State, Results of the Field Studies, University North Carolina at Chapel Hill and Institute of Nutrition of Central America and Panama (February 1978) pp. 84, Table IV-26.

munity, and Florida Aceituna, the control community, are both located in the Pacific Coastal Lowlands of Guatemala. Rainfall in both communities averages 2000 millimeters annually and falls predominantly in the period from May to October. Average annual temperature is 20 C. Soil conditions and housing are similar in both communities. Data on digestive disease for the period 1967-1971 are approximately 17 reported cases per 1000 inhabitants for each community. Each is relatively isolated from the other although both were approximately one hour's drive from the headquarters of the Institute of Nutrition of Central America and Panama (INCAP).

There were differences in the two communities that might have affected the results. The most important was the absence of men in the experimental community, who sometimes left to do farm work for extended periods.

Water Supply

The experimental community had an existing piped water system serving 13 families. This was retained and a new system was provided to serve 106 homes during the first period of data collection. By the end of the project, 65 percent of the experimental community had piped chlorinated water metered to individual patios while an additional 5 percent received piped unchlorinated water from the system existing prior to the project. There was some sharing of meters.

The control community received water from shallow wells and from the river. Over 70 percent used their own or a neighbor's well while 9 percent used the river. The source for the rest of the community was not determined.

By laboratory analyses, three quarters of the samples at the source and half the samples of water drawn from domestic containers in the experimental community were satisfactory, no fecal coliform present (Table 2). None of the water from containers in the control community was satisfactory.

Health Education

The health education component of the study had five objectives: to reduce fecal contamination of the area; to keep animals out of the homes; to promote construction of latrines; to improve food and water storage; and to increase water use for hygenic purposes. Program leaders trained residents who then were the health promoters in the village. The program was carried out by a committee of men, a committee of women, and a group of midwives and the school teachers.

The program started in April 1975, the last month of the fourth period of the study. The effects of the program, if any, would therefore be found in the subsequent three periods, between April, 1975, and September, 1976.

The objective of the male group, the Community Betterment Committee, was in general to encourage projects of benefit to the community. They did this in meetings with villagers to emphasize good sanitary practices. The Committee undertook a number of projects that included construction of latrines. Twenty of the group also completed a two-month training program and became health promoters.

The women were encouraged to participate in a number of extension classes that taught specific skills such as cooking or sewing, but also emphasized good personal and home sanitation. Practicing midwives were given formal training which included sanitation practices. At the conclusion of the training the status of the midwives was increased by providing them with professional registration and furnishing them with kits containing instruments, medicines and supplies.

School teachers participated in a three day workshop to plan a program for health education. The curriculum stressed basic hygiene, sanitary behavior and food and water hygiene. To encourage adoption of the lessons of the health curriculum school toilets and sinks were repaired or replaced and liquid soap, toilet paper, paper towels and cleaning supplies were provided.

Data Collection

Data on incidence of diarrhea were collected by female investigators who visited each family usually each month (Table 3). An individual, usually an adult female, was asked specifics about family health over the two preceeding weeks. Figures related in the study are therefore approximately half of the actual morbidity rates.

Data collected in this type of a survey are subject to problems of recall and of respondents' knowledge of the health of the family members. The low rates of morbidity reported for adults are probably the result of lack of knowledge of the respondent of the health of adults not in the home during most of the day. The first six months of the study indicate high rates of morbidity in both villages for all diseases. The study report attributes this to over-reporting on the part of the vilagers due to the new experience.

Data on water quality, water use, health attitudes and practices were collected from a group of users who were randomly selected at the beginning of the study. Once selected the same group, designated the longitudinal sample, was retained for the period of the study. Sampling procedure for water quality and water use was the same in both villages but changed at various times during the study from monthly to once in three months and finally once every other month.

Data Analysis

The study used a regression model to examine the health effects of a number of variables on rates of diarrhea. There were 63 variables in the control community. These included village, family size, month and sanitary conditions. An additional two variables were used in the experimental community, access to piped supply, and monthly water consumption.[1]

Data Reporting

Morbidity data were reported by age groups, by sex and by village. The data collection extended from May, 1973, through August, 1976, a period of forty months and included four rainy and three dry periods. For convenience, the seasons are designated by a number indicating order of the period and a letter: "R" for rainy and "D" for dry. Table 3 indicates the months and year for each of the seven data collection periods.

REPORTED RESULTS OF THE PROJECT

The effect of the program on quantity and use of water, on health knowledge and attitudes and on the building of latrines was well documented in the final report.

Water Use

The families with piped water supplies in the experimental community increased the water use on the average to more than twice that of the control community. The mean amount used per person over the project was 26 liters daily for each person in Florida Aceituna and 68.4 liters for each person daily in Guanagazapa (Table 4). The uses of water in the home rather than at the source also increased in the experimental community.

---

[1]Appendix C is an extract from the report giving the description of the linear model, fit, the independent variables and the results of the analyses.

Table 4

Volume of Water Use Experimental and Control Community for Seven Successive Six Month Periods (Liters/capita daily)

Period a/	Experimental b/	Control c/
1R	40.0	No data
2D	63.1	23.2
3R	62.9	24.7
4D	80.5	30.4
5R	70.1	23.7
6D	77.0	28.9
7R	73.5	24.6

a/ Data are from 7 periods outlined in Table 3. Successive periods were R (Rainy) and D (Dry).

b/ Experimental Community: Consumption collected on all families using the distribution system, usage computed from water meters. Usage above 200 l/p/d excluded.

c/ Control Community: Recall method used to compute usage, and usage above 200 liters per capita per day excluded.

Source: Final Report to the Agency for International Development, Department of State, Results of the Field Studies, University of North Carolina at Chapel Hill and Institute of Nutrition of Central America and Panama (February 1978) pp. 30, Table IV-8.

Eighty percent washed clothes and bathed at home in the experimental community compared to less than one-third who did laundry and one-fifth who bathed at home in the control community (Table 5) .

Attitudes and Knowledge

The study measured attitudes as well as behavior. The members of the longitudinal sample in both communities were interviewed six times after the health program began. Questions were asked about water quality, excreta disposal, health impact of animals and flies in the kitchen, knowledge about causes of diarrhea in children and adults, the relationship between personal hygiene and disease, germ theory, hand washing, and use of soap. The answers were used to form a health education scale. The experimental community showed a significant improvement in knowledge over the period of the health program (Table 6).

Latrine Construction

At the start of the project nearly a third of the homes (66) reported having a latrine although some were used infrequently, if at all. During the last three data collection periods 79 new latrines were installed in the experimental community, 39 of these were constructed in 1975, the balance in 1976. During this period there was almost no construction in the control community.

At the conclusion of the project a survey was made of the effects of the latrine program. All latrines built except one were in use. In addition, new latrines continued to be constructed at the rate of two a month after the project was completed.

Summary of Results Reported

The project did have an effect on the conditions that are assumed to affect diarrhea; however, the investigators found no evidence in the data analysis for a significant reduction in the rates of diarrhea in the experimental community. In the following sections we offer an alternative method of examining the data and reach different conclusions.

DATA RE-ANALYSIS

Contrary to the findings of the original investigators our analyses of the data show highly significant differences between diarrheal morbidity rates in the two communities. In comparing

Table 5

Uses of Water at the Home by Season Experimental and Control Community

Water Use	Seasons						
	1 Rainy*	2 Dry	3 Rainy	4 Dry	5 Rainy	6 Dry	7 Rainy
			Experimental Community				
Personal Hygiene	-	100	100	100	100	100	97
Food Preparation	-	100	100	99	100	100	100
Utensil Washing	-	100	100	99	100	99	97
Laundry	-	75	83	83	80	91	84
Bathing	-	75	79	80	80	91	79
			Control Community				
Personal Hygiene	-	100	92	100	98	98	100
Food Preparation	-	100	100	100	99	99	100
Utensil Washing	-	95	96	96	92	96	96
Laundry	-	28	23	33	31	30	19
Bathing	-	26	16	16	18	10	12

*No data available.

Source: Final Report to the Agency for International Development, Department of State, Results of the Field Studies, University of North Carolina at Chapel Hill and Institute of Nutrition of Central America and Panama (February 1978) pp. 34, Table IV-9.

Table 6

Changes in Perception Scale 1975-1976
Experimental and Control Communities

Weighted Sum of Scores of Health Attitude Variables						
	Periods					
	1975			1976		
Community	1[a]	2	3	4	5	6
Experimental	186	232	239	274	263	268
Control	183	211	205	214	219	219

a/ Prior to health education program. Differences significant (P= .05)

Source: Final Report to the Agency for International Development, Department of State, Results of the Field Studies, University of North Carolina at Chapel Hill and Institute of Nutrition of Central America and Panama (February 1978) pp. 102, Table V-3 the communities by age groups, by season, by sex, and by family size the diarrhea rates for the experimental community are significantly lower.

Diarrhea and Age

The average rates of diarrhea reported over the study period were 50 cases per 1000 in the control community and 38 cases per 1000 within the experimental community. Children between one and two years old had the highest reported rates in both communities. In the control community, the next highest rates were for those who were from two to seven years old. In the experimental community, the two to seven group had the third highest rate.

The lowest rates of diarrhea in both communities were among those 15 to 30 years old. For all age groups except infants and those 45 and older, the experimental community had lower reported rates. The differences between the rates of the two communities were statistically significant (Table 7).

The rates of diarrhea in the experimental community were substantially lower for all age groups except those less than one or over forty-five. This is true for both absolute differences in rates or percentage differences between communities. Among the age group from 7 to 15, the rate in the experimental community was 40 percent less than the rate for the same age group in the control community (Table 8).

One to Seven Age Group

The age group between one and two and the group from two to seven were responsible for the majority of diarrhea cases (53 percent in each community). It was this group that benefitted most from the improved supply. The decline from the very high levels reported at the outset was rapid and reached a rate of 51 per 1000 in the experimental community before trending upward (Table 9). This compared to a plateau of approximately 100 cases per 1000 in the control community over a two year period (Figure 1).

The decrease was highly significant. The Chi Square of differences between the two communities indicates a probability of less than .0001. In addition to being significant, the differences are systematic. The rates of diarrhea for the one to seven group in the experimental community when compared to the control group show a continuous trend of improvement over the 42 months (Figure 2).

Table 7 a/

Reported Cases of Diarrhea by Age Group
Experimental and Control Community
(2 week periods of each month)

Age Group	Experimental: Cases of Diarrhea	Experimental: No Diarrhea	Experimental: Rate/ 1000	Control: Cases of Diarrhea	Control: No Diarrhea	Control: Rate/ 1000	Total Cases
0-1	168	1249	119	186	1316	123	2919
1-2	290	1111	207	294	1031	222	2726
2-7	461	5936	72	576	4663	110	11636
7-15	189	8323	22	216	5560	37	14288
15-30	103	9031	11	141	8317	17	17592
30-45	68	4814	14	103	4893	21	9878
45+	133	5032	26	131	5079	25	10375
TOTAL	1412	35496	38	1647	30859	51	69414

Chi Square value for this table.....165.36

Degrees of Freedom................. 6

Minimum level (P= .005) required to reject the hypothesis that the experimental and control rates are not different......................18.548

a/ See Appendix A for discussion of statistical methodology for Table 7, 9, 11, 12, 13 and 14.

Table 8

Difference in Rates of Experimental and
Control Community Diarrhea All Age Groups
(Rates/1000)

Age Group	Rate Experimental Community	Rate Control Community	Difference in Rates (Experimental-Control)	Percentage Change[a]
0-1	119	123	-4	-3
1-2	207	222	-15	-7
2-7	72	110	-38	-35
7-15	22	37	-15	-41
15-30	11	17	-6	-35
30-45	14	21	-7	-33
45+	26	25	1	4

[a] Difference divided by Control Rate.

Table 9

Reported Cases of Diarrhea in Children One to Seven
Experimental and Control Communities

Six Month Periods							Rainy (R) and Dry (D)
	Experimental			Control			
Period	Cases of Diarrhea	No Diarrhea	Rate	Cases of Diarrhea	No Diarrhea	Rate	Total Observations
1 Rainy	203	864	190	160	714	183	1941
2 Dry	81	697	104	99	555	152	1432
3 Rainy	122	1185	93	118	948	111	2373
4 Dry	56	1043	51	95	867	99	2061
5 Rainy	106	1294	76	117	1080	98	2597
6 Dry	81	1091	69	115	878	116	2165
7 Rainy	100	874	103	111	711	135	1796
TOTALS	749	7048	96	815	5753	124	14365

Chi Square value for this table..........108.23

Degrees of Freedom...................... 6

Minimum level (P= .005) required to reject the hypothesis that the experimental and control rate are not different............................ 18.548

For additional note, see Appendix A

Figure 1

Reported Cases of Diarrhea Children 1 to 7 Years
Two Week Periods of Each Month of Data Collection
Seven Six Month Periods: Alternatively Rainy and Dry
(Cases per 1,000)

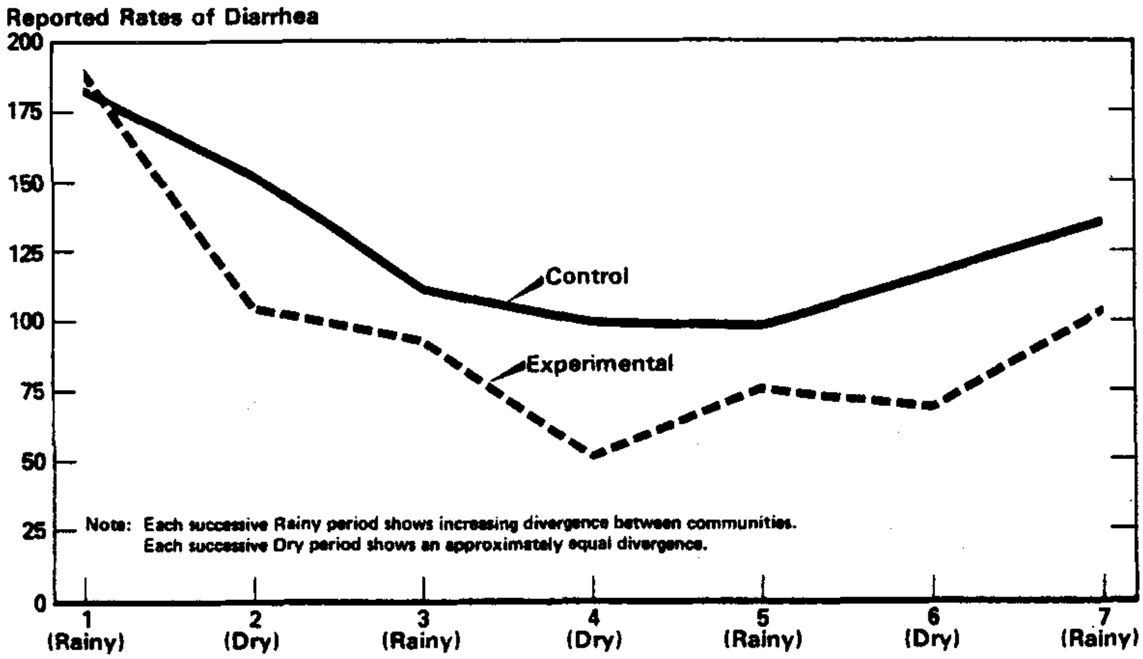
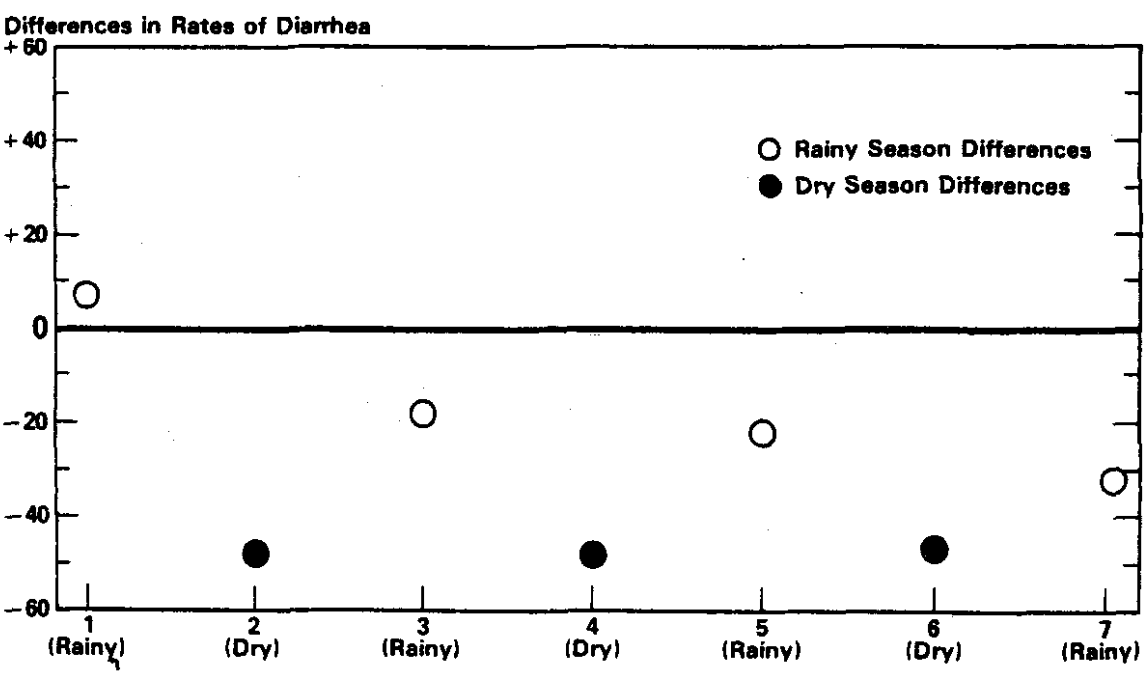


Figure 2

Differences in Rates of Diarrhea, Children 1 to 7 years
Experimental — Control
Seven Six Month Periods: Alternatively Rainy and Dry



Diarrhea and Season

Rates of diarrhea were lower during the dry season than the wet season in both experimental and control communities. The difference between seasons was greater in the experimental community where there was a reduction of one-third compared to a reduction of one sixth in the control community. The comparison between communities showed a difference of 16 percent in the wet season and more than twice as much in the dry season.

The effect of season can be shown most conclusively for the age group from one to seven. The rainy season rate in the experimental community is 15 percent less than the control community. Dry season rates are 40 percent less in the experimental community.

Diarrhea rates in the first dry season declined by 48 cases per 1000 and maintained approximately the same absolute difference throughout the project. The rainy season rates of the experimental community were higher at the start of the project with each successive rainy season showing an increasing decline in both absolute rate and in percentage decline (Table 10).

Diarrhea and Water Use

Within the experimental community volume of water use was inversely related to the rate of diarrhea for the season. The correlation coefficient between the rate of diarrhea for the entire community and the average water use per capita was very high ($r^2 = .97$). This relationship was statistically significant ($p = .001$).

Other Groupings[2]

A number of other analyses were prepared. A comparison was made of males and females in each of the villages both by age group and by season. While there are substantial differences between the sexes within the village, those in the experimental community have significantly lower overall rates of diarrhea. In addition the patterns of improvement for each of the sexes are consistent with the findings for male and female combined.

The study reported a difference in morbidity rates among large and small families. Our analysis confirms that there is a significant difference between communities when controlling for family size (Tables 15 and 16).

---

[2]Appendix B contains tables 11-16 that illustrate the data reported in this section.

Table 10 [3]

Seasonal Difference in Rates of Diarrhea One to Seven Age Group
Experimental Community Rate Minus Control Community Rate

Period	Experimental Community	Control Community	Difference in Rates: Amount: Rainy Season	Amount: Dry Season	Percentage a/: Rainy Season	Percentage a/: Dry Season
1R	190	183	+7		+4	
2D	104	152		-48		-32
3R	93	111	-18		-16	
4D	51	99		-48		-48
5R	76	98	-22		-22	
6D	69	116		-47		-41
7R	103	135	-32		-24	
Average difference			-16	-48	-15	-40

a/ Difference divided by control rate.

General Note on This and Following Tables

3/ There remain, after painstaking effort, several minor discrepancies in the following tables. These errors all exist in the source data and could not be identified or resolved using the available information. The reader should be aware, however, that these minor discrepancies would not affect the statistical conclusions drawn from these data: the observed experimental/control difference in diarrhea rates are vastly larger than the discrepancies in the tables.

CONCLUSIONS

Using the same set of data as the original investigators we have shown significant changes in rates of diarrhea in a community where most of the population had access to a piped chlorinated water supply. The original investigators reported:

> One can conclude from these analyses that changes in sanitary quality of the magnitude observed in these villages did not produce striking changes in morbidity over the relatively short period of this study. Some very small trends or associations with sanitation may have been detected. For example, increased water consumption in Guanagazapa was associated with decreased diarrhea and skin infections in children aged 13-24 months, but the trends or associations are so small that it is not possible to 'separate the signal from the noise'.[4] (Results of the Field Studies, p. 51.)

We have used a Contingency Table method of data analyses and a Chi Square test of significance. This shows highly significant and systematic differences between the two communities. The original study used a large multiple regression model with 63 variables in the control community and 65 variables in the experimental community. The regression methodology is described in Appendix C.

We believe that the contingency table analysis using the cases in the experimental community as the observed and the cases in the control community as the expected represents an appropriate test of significance.

The reduced rate of diarrhea is statistically significant among all age groups with the exception of those under two and forty-five or older. The data indicate significant and systematic differences for males, females, large families, small families, wet season and dry season.

The following conclusions are tentative and a definitive analysis will require access to additional data not contained in the reports to A.I.D. However, the data suggest that water alone was a sufficient condition to result in decreased diarrheal rates. The extensive health program and increased use of latrines do not appear to have resulted in an accelerated trend of decrease on diarrhea in the last three six-month periods of data collection. These conclusions if validated in the further analysis based on more complete data would have far-reaching implications.

---

[4]Emphasis added.

FUTURE RESEARCH

The results reported in this paper represent a reconstruction and re-analysis of the available data, that available in the various reports to USAID. A more extensive examination of the data is warranted. The study has met all the criteria recommended by an expert panel for measuring health benefits convened by the World Bank (IBRD, 1976). The data, therefore, should provide the necessary precision to provide a basis for design of rural water systems to ensure that they provide the best balance between system cost and users' benefits.

The more extensive analysis should provide answers to specific questions on chlorination, latrines, health education, and nutrition and how these variables are inter-related. A final analysis would consist of the construction of multi-way contingency tables that will show health status as a function of nutritional status, the availability and quality of water, personal and community environmental factors, socio-economic factors, family size and season.

Data analysis for this paper was under the supervision of Joseph Quinn, survey statistician with the International Statistical Program Center of the Bureau of the Census who suggested the methodology and reconstructed the data from the study reports.

The authors are indebted to a number of people who have read and commented on earlier versions of this paper. These include Abel Wolman of Johns Hopkins University; Morris Shiffman of the University of North Carolina; Boyd McCleary of the University of Michigan School of Public Health; William Menth of the Bureau of the Census; Robert Berg, AID, Alfred Buck, AID; Graham Kerr, AID; F.W. Montanari, AID; and Barbara Pillsbury, AID.

References

Briscoe, J.: The Role of Water Supply in improving health in poor countries (with special reference to Bangla Desh). The American Journal of Clinical Nutrition 31: 2100-2113, 1978.

Feachem, R., E. Burn, S. Cairncross, A. Cronin, P. Cross, D. Curtis, M. K. Khan, D. Lamb, and H. Southall: Water, Health and Development. London, Tri-Med Books, 1978.

Hardy, W. V. and J. Watt.: "Studies of Acute Diarrheal Diseases". Epidemiology (PHS) 63: 363-378, 1948.

Hollister, A. C., Jr., M. D. Beck, A. M. Gittlesohn, and E. C. Hemphill: Influence of water availability of Shigella prevalence in children of farm labor families. American Journal of Public Health 45: 354-362, 1955.

International Bank for Reconstruction and Development. Measurement of the health benefits of investments in water supply. Washington, D.C.: International Bank for Reconstruction and Development, 1976.

Kawata, K.: Of typhoid fever and telephone poles: deceptive data on the effect of water supply and privies on health in tropical countries. Progress in Water Technology 11: 37-43, 1978.

Levine, R. J., M. R. Khan, S. D'Souza, and D. Nalin: Failure of sanitary wells to protect against cholera and other diarrhoeas in Bangladesh. Lancet 2: 86-89, 1976.

Moore, H. A., E. De La Cruz and O. Vargas. Diarrheal disease studies in Costa Rica: IV, the influence of sanitation upon the prevalence of intestinal infection and diarrheal disease. American Journal of Epidemiology 82: 162, 1966.

Schliessmann, D. G., F. O. Atchley, M. J. Wilcomb, Jr., et al. Relation of Environmental Factors to the Occurrence of Enteric Diseases in Areas of Eastern Kentucky (PHS Publication No. 591). Washington, D.C., Government Printing Office, 1958.

Schneider, R. E., M. Shiffman, and J. Faigenblum: The potential effect of water on gastrointestinal infections pervalent in developing countries. The American Journal of Clinical Nutrition 31: 2089-2099, 1978.

Shiffman, M. A., R. Schneider, J. M. Faigenblum, R. Helms and A. Turner: Field Studies on Water Sanitation and Health Education in Relation to Health Status in Central America. Progress in Water Technology 11: 143-150, 1978.

University of North Carolina at Chapel Hill and Institute for Nutrition of Central America and Panama. Results of the Field Studies: Food Wastage/Sanitation Cost-Benefit Methodology Project (AID/csd-2959) 1978.

_________ Methods for Field Studies: Food Wastage/Sanitation Cost-Benefit Methodology Project (AID/csd-2959), 1978.

_________ Assessment and Policy Implications: Food Wastage/ Sanitation Cost-Benefit Methodology Project (AID/csd-2959), 1978.

Walsh, J. A., and K. S. Warren: Selective Primary Health Care: An Interim Strategy for Disease Control in Developing Countries. New England Journal of Medicine 301: 967-974, 1979.

Watt, J., M. D. Beck, E. C. Hemphill: Diarrhoeal Diseases in Fresno County California. American Journal of Public Health 43: 728-741, 1953.

White, G. F., D. J. Bradley, and A. U. White: Drawers of Water: Domestic water use in East Africa. Chicago, University of Chicago Press, 1972.

APPENDIX A

CALCULATION OF CHI SQUARE

APPENDIX A

Calculation of Chi Square

The X^2 statistic is used to compare the differences in diarrhea rates between the experimental and control villages and is computed as:

$$\sum \frac{(\text{actual cases} - \text{expected cases})^2}{\text{expected cases}}$$

The summation is done over the 7 age groups as follows (From Table 7):

Age Group	Observed Cases in Experimental Village	Expected Cases Based on Control Village Rates 1/	(Actual-Expected) / Expected
	168	174	0.20
	290	311	1.42
[illegible]	461	704	83.88
7-15	189	315	50.40
15-30	103	155	17.45
30-45	68	103	11.89
45+	133	129	0.12
TOTAL	1,412	1,891	X^2=165.36 2/

(1) For example, the 0-1 age group is computed as

(control village rate X total experimental village cases)

0.123 X (168 + 1,249) = 174.29, rounded to 174.

(2) The critical value for this statistic is 18.548 based on 6 degrees of freedom and a 0.005 level of significance. The X^2 statistic obtained (165.36) is therefore highly significant and indicates extreme differences in the diarrhea rates between the villages.

CONCLUDING NOTE

There are several alternative formats for making this computation, and in each instance, the X^2 statistic is highly significant. The rationale for the method chosen is that it is not subject to distortion by the differences in the proportion of population in each age grouping or the differences in the number of measurements taken. This method was used for subsequent calculations in Tables 9, 11, 12, 13, 14, 15 and 16. In each case, the hypothesis being tested is that there are no difference in the diarrhea rates between the experimental and control villages. Accordingly, an X^2 value over 18.548 (which could occur by chance alone only 0.5 percent of the time or one time in 200) indicates that the hypothesis must be rejected in favor of the alternative hypothesis that diarrhea rates are significantly different between the experimental and control villages.

APPENDIX B

SUPPLEMENTARY TABLES

Table 11

Diarrhea Incidence in Females By Age Group Experimental and Control Community

	Experimental			Control		
Age Group	Cases of Diarrhea	No Diarrhea	Rate	Cases of Diarrhea	No Diarrhea	Rate
Previous Page Blank	76	688	99	81	763	96
1-2	162	614	209	151	519	225
2-7	231	2,876	74	259	2,360	99
7-15	116	4,289	26	103	2,443	41
15-30	56	4,122	13	91	3,931	23
30-45	32	2,461	13	62	2,006	30
45-	80	2,342	33	78	2,205	34
Totals	753	17,392	41	825	14,227	55

Chi Square value for this table	85.04
Degrees of Freedom	6
Minimum level required (p=.005) to reject the hypothesis that the experimental and control rates are not different	18.548

For additional note, see Appendix A

Previous Page Blank

Table 12

Diarrhea Incidence in Males By Age Group Experimental and Control Community

	Experimental			Control		
Age Group	Cases of Diarrhea	No Diarrhea	Rate	Cases of Diarrhea	No Diarrhea	Rate
0-1	92	561	141	105	553	160
1-2	128	497	205	143	512	218
2-7	230	3,060	70	317	2,303	121
7-15	73	4,034	18	113	3,117	35
15-30	47	4,909	9	50	4,386	11
30-45	36	2,353	15	41	2,887	14
45+	53	2,690	19	53	2,874	18
TOTALS	659	18,104	35	822	16,632	47

Chi Square value for this table	109.51
Degrees of Freedom	6
Minimum level required (p=.005) to reject the hypothesis that the experimental and control rates are not different	18.548

For additional note, see Appendix A

Table 13

Diarrhea Incidence By Period for Females Experimental and Control Communities

	Experimental			Control		
Season	Cases of Diarrhea	No Diarrhea	Rate	Cases of Diarrhea	No Diarrhea	Rate
1 Rainy	213	2,241	87	244	1,755	122
2 Dry	80	1,807	42	98	1,393	53
3 Rainy	114	2,979	38	110	2,297	46
4 Dry	65	2,526	25	85	2,129	38
5 Rainy	96	3,088	30	107	2,639	39
6 Dry	85	2,634	31	108	2,188	47
7 Rainy	100	2,117	45	93	1,806	49
TOTALS	753	17,392	41	845	14,207	56

Chi Square value for this table	77.96
Degrees of Freedom	6
Minimum level (p=.005) to reject the hypothesis that the experimental and control community rates are <u>not</u> different	18.548

For additional note see Appendix A

Table 14

Diarrhea Incidence By Period for Males Experimental and Control Communities

	Experimental			Control		
Season	Cases of Diarrhea	No Diarrhea	Rate	Cases of Diarrhea	No Diarrhea	Rate
1 Rainy	203	2,394	78	205	2,153	87
2 Dry	66	1,728	37	95	1,673	54
3 Rainy	92	3,003	30	104	2,777	36
4 Dry	56	2,556	21	104	2,475	40
5 Rainy	91	3,349	26	121	3,097	38
6 Dry	69	2,761	24	93	2,559	35
7 Rainy	82	2,313	34	100	2,098	45
TOTALS	659	18,104	35	822	16,832	47

Chi Square value for this table	65.21
Degrees of Freedom	6
Minimum level required (p=.005) to reject the hypothesis that the experimental and control rates are <u>not</u> different	18.548

For additional note, see Appendix A

Table 15

Diarrhea Incidence By Period in Families With Five Or More Persons
Experimental and Control Communities

Season	Cases of Diarrhea	No Diarrhea	Rate	Cases of Diarrhea	No Diarrhea	Rate
1 Rainy	349	3,485	91	347	2,775	111
2 Dry	123	2,681	44	142	2,193	61
3 Rainy	164	4,533	35	148	3,641	39
4 Dry	67	3,882	17	124	3,311	36
5 Rainy	141	4,887	28	158	4,115	37
6 Dry	114	4,098	28	145	3,400	41
7 Rainy	147	3,354	42	156	3,780	53
TOTALS	1,105	26,910	39	1,220	22,215	52

Chi Square value for this table	107.68
Degrees of Freedom	6
Minimum level required (p=.005) to reject the hypothesis that the experimental and control rates are not different	18.548

For additional note, see Appendix A

Table 16

Diarrhea Incidence By Period in Families With Less Than Five Persons
Experimental and Control Communities

	Experimental			Control		
Season	Cases of Diarrhea	No Diarrhea	Rate	Cases of Diarrhea	No Diarrhea	Rate
1 Rainy	67	1150	55	82	1153	66
2 Dry	23	864	26	51	873	55
3 Rainy	42	1149	28	66	1433	44
4 Dry	54	1200	43	65	1293	48
5 Rainy	46	1550	29	70	1621	41
6 Dry	40	1297	30	56	1347	40
7 Rainy	35	1076	32	37	1124	32
TOTALS	307	8586	35	427	8844	46

Chi Square value for this table 33.98

Degrees of Freedom..................... 6

Minimum level required (P= .005) to
to reject the hypothesis that the
experimental and control rates are
not different........................ 18.548

For additional note, see footnote
Appendix A

APPENDIX C

STUDY METHODOLOGY

APPENDIX C

STUDY METHODOLOGY

Data Analyses For Morbidity-Sanitation-Water Associations[1]

The combined census, morbidity, and sanitation data have been examined quite extensively by general linear and categorical models in an attempt to reveal any significant relationships between any of four types of morbidity dy's measures of household sanitary quality or changes in sanitary quality. All of the analyses were adjusted for known "noise factors" such as month-to-month variability or seasonal differences. The analyses also included adjustments for, or took account of, factors such as age, sex, size of family and village, which are believed to influence morbidity. The results were adjusted for these factors so that the effects of sanitation could be estimated and tested "clearly", free of the possible effects of other characteristics, which might also affect morbidity. Four classes of morbidity were examined exhaustively: skin infections, infectious diseases, respiratory diseases and diarrhea. The sanitary measurements, which were examined, came from three survey instruments (see Methodology): Monthly Sanitation Survey (Form 32), Water Consumption and Usage (Form 37) and Water

---

[1]This section is extracted from Final Report to the Agency for International Development, Department of State, Results of the Field Studies, University of North Carolina at Chapel Hill and Institute of Nutrition of Central America and Panama, pp. 41-62 (Table and Some References Deleted).

Quality Survey . . .

Unfortunately, perhaps, the results of these analyses may be succinctly summarized. The variables which were "controlled for" in the analyses, such as age, community, month (or quarter or season), and size of family were typically shown to have discernable effects on morbidity. The sizes of the estimates of the effects were different for the different types of morbidity and also varied from analysis to analysis, depending upon the "adjustment variables" being used.

In contrast, there were no sanitary status variables which showed persistent effects on morbidity. That is, if a statistically significant

in one group, the effect would not be significant for another for example, a group with identical characteristics except for a difference in age or sex. Moreover, when statistically significant effects were plotted on graphs, the "effects" proved to be very indefinite.

One can conclude from these analyses that changes in sanitary quality of the magnitude observed in these villages did not produce striking changes in morbidity over the relatively short period of this study. Some very small trends or associations with sanitation may have been detected. For example, increased water consumption in Guanagazapa was associated with decreased diarrhea and skin infections in children aged 13-24 months, but the trends or associations are so small that it is not possible to "separate the signal from the noise." A large number of statistical tests were performed in these analyses and the proportion of "statistically significant" test results was near 5%, about what would be expected when testing at the 5% significance level. It was therefore difficult to determine if effects, such as the one noted above, are real or the result of random variability. Using scatter diagrams, in which morbidity is plotted against

Previous Page Blank

water consumption [actually, $\log_{10}$ water consumption], it is apparent that even if an effect exists, it was quite small over the time period of this study and is masked by random variability in morbidity experience.

A comprehensive description of one statistical analysis, which indicates the complexity of the models and the number of variables involved, is presented here. This type of analysis was done for all variables of interest.

1. General Linear Model Analysis of Family Monthly Morbidity Data for Associations with Monthly Sanitation Survey Variables

The influence of water consumption and sanitary behavior upon morbidity was examined using the monthly family morbidity data. For each family, morbidity rates were computed each month for four categories of morbidity (respiratory diseases, skin infections, diarrhea, and infectious diseases). In this analysis, observations on a particular family in different months were treated as independent. For three of the disease categories (skin infections, respiratory diseases, and infectious diseases), the empirical evidence (i.e., month-to-month correlations over families) indicates that this assumption is justified. For diarrhea, correlation of "within family morbidity" was found, but the magnitude was so small that the effect on the results is minor. It should be noted that the effect of such correlations would be to increase bias in the tests of hypothesis. Thus for diarrhea, marginally significant results must be viewed with some caution.

General linear model techniques were used to examine the effect of the various predictor variables on the morbidity rates. The factors studied were:

a. Village. Florida Aceituno versus Guanagazapa

b. Family size. 1, 2, 3, 4, and 5+ family members

c. Month. Thirty-five calendar months for which morbidity data were available

d. Sanitary Condition Variables. An indication of whether or not a sanitary survey (Form 32) was made on this family during the month and, if so, sanitary condition as assessed by each of eleven questions from Form 32.

e. Longitudinal Sample Membership. An indication of whether or not this family was a member of the longitudinal sample.*

f. Water Consumption (in Guanagaza only). An indication of whether or not the family had piped water, and if so, monthly water consumption.

For each of these factors, a number of indicator variables were created. The precise form of these variables will be described in a subsequent section.

In the course of the preliminary examination of these data, it became evident that the variance of the morbidity rates changed as a function of family size, large families showing greater variability. In order to deal with this, it was necessary to use weighted least squares techniques, a straightforward generalization of ordinary least squares....

2. General Description of the Models Fit

For practical purposes, one can consider that eight separate models were fit, one for each of the four morbidity categories in each village. At a later stage, the two "within village models" for each morbidity type were combined in order to assess interactions of the various other factors with village. The general structure of all eight models is identical. The model described in this section is thus the model applicable in each case. The form of the model is:

*The longitudinal sample is described in the Methodology report for the project. Membership in the sample is based on the participation of a family member in the Detailed Absorption Studies....

$$Y_i = \sum_{j=1}^{p} X_{ij}\beta_1 = e_i \ , \ i=1,2,\ldots,N.$$

Y_i is the observed morbidity rate for the i-th family in a specific month (in FA, N=7715 observations; in GU, N=7619 observations). X_{ij} is the value of the i-th observation (family for a particular month) on the j-th "independent variable". These independent variables were computed from the factors listed above and described in the next section. In Florida-Aceituno 63 such variables were used while in Guanagazapa 65 were used.

$e_i = Y_i - \Sigma_j X_{ij}\beta_j$ is the observed morbidity rate (Y_i) minus the "model predicted" morbidity rate, $\Sigma_j X_{ij}\beta_j$. We assume e_i is random and arises from a distribution with a zero population mean and a population variance which depends upon community, family size, and type of morbidity rate.

It is not possible to know the exact values of the β_j, the model's primary parameters. The method of weighted least squares is used to estimate the β_j and the estimate of β_j is called b_j. The precision of the estimate, b_j, is indicated by its standard error.

3. Description of Independent Variables in the Model and Corresponding Primary Parameters

One or more independent variables were created from each of the factors listed above. Most of these were "indicator variables" which take on only values of 0 or 1. For example, one independent variable in the model was an indicator variable which corresponds to longitudinal family membership. This variable has a value of 1 if the observation comes from a longitudinal sample family and 0 otherswise. In some cases, more than one indicator variable was generated corresponding to family size. Every observation has a 1 in each of the indicator variables, its position depending on the number of people in the family. . . .

TABLE IV.15

Formation of Family Size Indicator Variables

		Indicator Variable 1	2	3	4
Family Size	1	1	0	0	0
	2	0	1	0	0
	3	0	0	1	0
	4	0	0	0	1
	≥5	0	0	0	0

Corresponding to each such variable is a β_j, one of the primary parameters. The model parameters, rather than the study variables, are used here because they are more meaningful.

The primary parameters were grouped to represent the effects on morbidity attributable to:

a. Family size (Variables: vvFAM1 - vvFAM4)

b. Calendar month (Variables: vvMNTH1 - vvMNTH35)

c. Environmental conditions (Variables: vOBSFAMO - vLATCL1)

d. Participation in the environmental survey (Variable: vHAV32)

e. Membership in the longitudinal sample (Variable: vLNGSAMP)

f. Having piped water and water consumption (Guanagazapa only). (Variables: GHAVWAT, GLOGFMWT).

[Note: vv denotes the letters FA or GU; v denotes the letter F or G, depending on the village involved.]

Monthly "Adjusted" means

The data for this analysis included 35 calendar months and the model includes one parameter for each month. The estimate of the parameter corresponding to a particular month is the adjusted mean morbidity rate for the month for families satisfying the following conditions:

a. Family size: 5 or more

b. Month: the specified month

c. Environmental conditions: not surveyed

d. Participation in environmental survey: Not surveyed

e. Membership in longitudinal sample: Family not in longitudinal sample

f. Piped water supply: Family does not have access to piped water supply

These conditions are called the "reference levels" of these factors.

For practival purposes, a separate model was fit to data from each of the two villages. Each monthly mean was "adjusted" for the other variables to reflect the values of the six variables given above. Thus, for example, the adjusted mean diarrheal morbidity rate for Guanagazapa families in May 1973 (month 7305) was 35.9 ± 7.2(adjusted mean ± standard error) incidents reported per thousand persons (Figure IV.12) while the corresponding rate in June, 1973 (7306) was 130.5 ± 7.1 (adjusted mean ± standard error). The corresponding rates in Florida Aceituno (Figure IV.12) were 52.9 ± 8.4 in May 1973 and 168.4 ± 8.3 in June, 1974. . . .

The parameters (and estimates) corresponding to family size represent the average difference in morbidity rate between families of a given size and families having 5 or more members if all other factors are equal. Thus, the coefficient for family size = 1 ... has a value of -25.8 ± 4.4 (coefficient ± standard error). This means that in Guanagazapa, other factors being equal, single-person families had an average diarrheal morbidity rate 25.8 ± 4.4 units below the rate for Guanagazapa families of 5 or more persons. Similarly, the family size =2 coefficient indicates Guanagazapa families of two persons had an average diarrheal morbidity rate 10.3 ± 4.1 units below the rate for Guanagazapa families of 5 or more persons. Families of 3 persons and those of 4 persons had essentially the same rates as the 5+ person families, the estimated difference being 0.4 ± 3.9 units lower for size 3 families and 1.4 ± 3.6 units higher for 4 person families. Table IV.16 presents the increments for mean diarrheal morbidity rates for families of sizes 1, 2, 3, and 4 compared to families of 5 or more persons averaged over months and for "reference levels" of the other factors.

The parameter corresponding to longitudinal sample membership represents the average difference in morbidity between families in and not in the longitudinal sample, holding the other factors constant at their reference levels. Thus, one can see from Table IV.16 that, in Guanagazapa, mean diarrheal morbidity for families in the longitudinal sample was 2.2 ± 2.6 units higher than the rate for families not in the sample. In Florida Aceituno, families in the longitudinal sample had mean diarrheal morbidity rates 2.9 ± 2.8 units higher than those not in the longitudinal sample, with all other factors again held constant at their reference levels.

One parameter in the model corresponds to the incremental effect on morbidity of having been surveyed with a Form 32 in a given month in comparison to the reference condition of not having been surveyed. Thus, on the average . . . families who were surveyed had diarrheal morbidity rates 118.3 ± 71.6 units higher in Florida Aceituno and 1.5 ± 108.7 units lower in Guanagazapa than families who were not surveyed.

In addition, the model has 11 pairs of parameters, each pair corresponding to one sanitation variable from Form 32. The reference level for each Form 32 variable is "not surveyed". For each variable, the first of the two parameters represents the increment in morbidity associated with a negative response for the particular Form 32 variable. "Negative response" means that response which, for any particular item, corresponds to a less sanitary condition regardless of whether this was coded as a yes or a no answer to a particular sanitary condition. Diarrheal morbidity for families in Florida Aceituno with a negative response to the variable K_FLIES (i.e., families who had flies in the kitchen) was on the average, 6.1 ± 16.5 units lower than that for families who were not surveyed (Table IV.17). The second parameter represents the increment in morbidity corresponding to a positive response in relation to the negative category (not in relation to the reference level). Thus, families with a positive response to K_FLIES in Florida Aceituno had a mean diarrheal morbidity rate -10.5 ± 7.9 units lower than families with a negative response. For K_FLIES, then, the average difference in diarrheal morbidity between the families not surveyed and those with positive responses is 6.9 ± 10.5 = 17.4 units. The pairs of parameters for the ten other Form 32 variables were defined by the same analogy.

In Guanagazapa, the model has two parameters for water consumption. The first is simply the incremental effect of having a water tap beyond the reference level of "no tap". Families with a water faucet had an average rate of diarrheal morbidity 20.5 ± 15.1 units higher than that of families without. The second water parameter is the coefficient of the $\log_{10}$ of the monthly family water consumption in liters per person per day. Thus, it is the slope of a regression line relating morbidity rate to amount of water consumed. The estimate of this slope is -6.3 ± 3.8 units for this effect. Hence, the trend of the relationship is for diarrheal morbidity to decrease as water consumption increases (with all other factors held constant).