C.1 PN-AAM-993
ISN-29569
PN-9310867/68

Final Report to the
Agency for International Development
Department of State

Assessment and Policy Implications

Food Wastage/Sanitation Cost-Benefit
Methodology Project (AID/csd-2959)

Submitted by

University of North Carolina at Chapel Hill

July 31, 1978

Table of Contents

Chapter		Page
I.	Introduction	1
	Hypotheses.....3	
II.	Summary of Results for Sanitation and Morbidity	5
	Demography.....5	
	Morbidity.....5	
	Water Supply and Sanitation.....7	
	Home Sanitation.....8	
	Health Education.....11	
	Level-of-Living Indexes.....12	
III.	Implications for Sanitation and Water Supply Programs	14
	Water Supply.....16	
	Sanitation.....18	
	Health Education.....21	
IV.	Summary of Results of the Food Wastage Study	23
	Intestinal Absorption Studies.....24	
	Studies on the Village Population.....28	
	Food Wastage.....30	
	Economic Losses from Food Wastage.....33	
V.	Implications for Future Studies	35
VI.	Other Relevant Variables	42
	Health Education.....42	
	Dietary Influences.....45	
	Economic Analysis.....45	
	Food Wastage Calculation.....47	
VII.	Policy Implications	52

I. Introduction

The "Food Wastage/Sanitation Cost-Benefit Methodology Project" is within the scope and focus of policy research. Rothwell[1] notes that such research is directed to the disclosure of regularities in human behavior, and therefore, provides a clearer basis for social planning. This study on the consequences of introducing water supply and sanitation may be characterized as a project-impact study. However, as with all policy research, the outcome is a contribution to planning. Under ideal conditions, policy research should offer the techniques that can make the assumptions explicit and the tests for establishing the validity of the assumptions. The Agency for International Development sponsored this policy research project in the relationship of water-related diseases and health benefits. The study was conducted in rural lowland Guatemala by the University of North Carolina at Chapel Hill and the Institute of Nutrition of Central America and Panama in Guatemala.

Policy research is characterized through use of the skills and methods of diverse disciplines to provide insight to the multiple variables and linkages that characterize real-world problems and solutions. The A.I.D. objectives for the study may be summarized by reference to an excerpt of the contract with the prime contractor (UNC-CH).

> The objective of this contract *per se* is to develop, field test and prepare a manual describing a methodology which can be utilized to determine the economic relationship between different levels of improved environmental sanitation and the waste

---

[1] Lerner, D. and Laswell, H.D. (eds.), "The Policy Sciences", Stanford Univ. Press, Stanford. 1976.

of food energy from (1) inefficient absorption of food in the intestinal tract, and (2) intestinal diseases transmitted under unsanitary conditions. The contractor will establish in cost-effectiveness terms the individual and synergistic influence of various environmental improvements on intestinal disease morbidity and associated food waste, and (b) determine the optimum combination of measures which, under existing economic, social and cultural constraints can most enhance efficient food utilization and reduction in morbidity.

Policy research, because of its requirement for applications to existing problem situations is tied to the perception of these problem situations at a given time. Kuhn[1] proposes that scientific research at any given period is carried on within an instrumental and conceptual framework accepted by an entire scientific community. The resultant mode of scientific inquiry then leads to a point where current problems cannot be resolved within the accepted framework. The scientific community then proceeds to a new conceptual structure or paradigm to govern the search for new facts.

It may be useful to explore the changes in the "paradigm" for water supply/health benefits research from the late 1960's (when the contract was proposed) and the present. The victories for disease prevention in the industrial countries based on treated water supplies led to the conviction that this pattern could be duplicated in the less developed countries through the introduction of piped water supplies of high quality. This view is still expressed with confidence and is historically demonstrable for the industrialized countries, however the demonstration must include all the other changes in housing, nutrition, and economics that also occurred in the industrialized countries at this period. In any event, the experimental verification for the water supply/disease

---

[1] Kuhn, Thomas S., "The Structure of Scientific Revolutions", Univ. of Chicago Press, Chicago. 1962.

link has not been clearly demonstrated for the warm, poor, rural areas of the world. The confidence in establishing the project-impact link was lessened by difficulties in establishing the etiology of diarrheal disease and other "fuzzy" variables in the proposed equation.

The "classic" water supply project-impact was further questioned on the basis of economic justification for water supply projects. The UNC/INCAP project is a lineal descendent of several project-impact studies initiated by the economists' request for criteria for allocation of resources between water supplies and other sectors. The public health virtue of water supply investment was not considered sufficient for decision-making and investments in water supply were to be considered in the framework of economic analysis. During the late 1960's there were already doubts expressed in the literature about the feasibility of evaluating health, social or productivity outputs in terms of economic units. The emphasis on "food wastage" attributed to a diminished intestinal absorptive capacity seemed to offer a readily measurable system of inputs and outputs, definable in terms of energy and chemical constituents, which were calculable in terms of economic units.

A conceptual scheme for pathways and linkages between water supply improvement, health behavior and economic change is shown in Figure 1. The statement is somewhat illusionary in terms of measurement potential. However, the conceptual scheme is helpful in understanding the hypotheses for the study. These hypotheses were:

A.) A population living under unsanitary conditions will have an increased prevalence of diarrheal morbidity. Improvements in sanitation (with emphasis on water supply) will diminish diarrheal morbidity.

This hypothesis was tested through the provision of a piped water

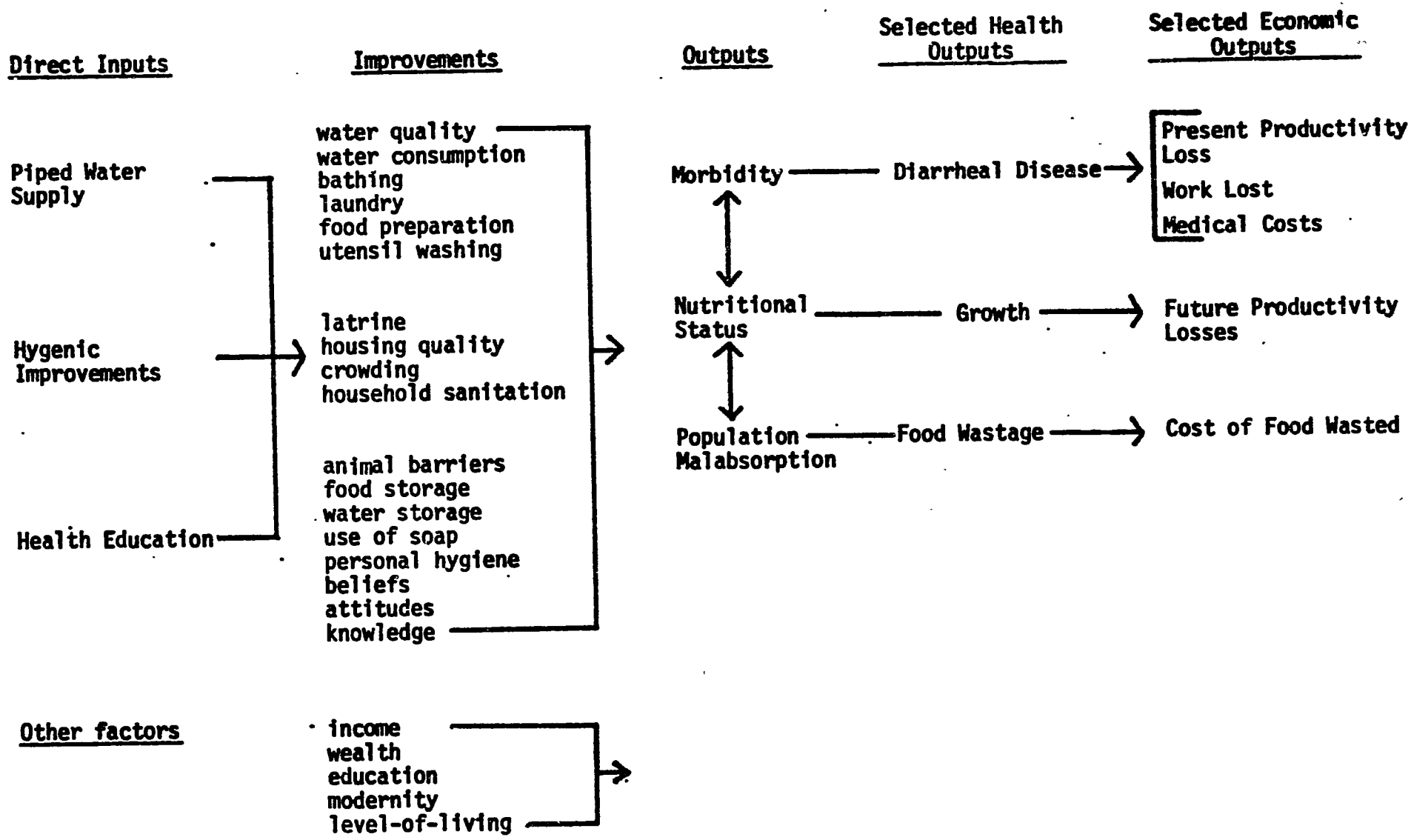


Figure 1. Conceptual Scheme for Linkage Between Environmental Improvement, Health and Economic Change

supply to each house in the experimental village. At a later stage of the project, educational and community development programs were introduced to encourage the sanitation-related use of water and to promote improved sanitation behavior patterns. The objective of these inputs was to improve water quality, availability, convenience and utilization by the village population. A control village, where no inputs were introduced, was used for comparison. Florida Aceituno was the control village and Guanagazapa was the test village.

B.) A population with a high prevalence of diarrheal morbidity may waste increased amounts of food as compared to a population with a lower prevalence of diarrheal morbidity. The food wastage is a consequence of repeated incidents of diarrheal disease which eventually traumatize the intestinal tract and results in malabsorption. There is reduced absorption during the diarrheal incident, however, this acute loss is considered separately from the losses due to chronic malabsorption.

Food ingested and then lost through intestinal malabsorption may constitute an economic loss and may be assessed in terms of wasted energy, non-utilized nutrients, direct food costs and losses in agricultural production.

The verification of these hypotheses required the assessment of inter-relationships and the measurement of a large number of variables. These variables included health status, dietary and nutritional status, anthropometry, intestinal efficiency, health behavior and other biomedical, economic, social and demographic characteristics of the village populations. The results of the study are presented with reference to these individual variables and their relationships.

II. Summary of Results of the Study for Sanitation and Morbidity

Demography

The objectives of the demography studies were to establish the comparability of the test and control villages. The villages were comparable in respect to their population sizes, age and sex distribution and family structure. Both villages showed a high degree of mobility. Villagers moved because of seasonal occupational requirements, however, there was also an extensive long term in and out migration. This finding is of some consequence since the usual perception of rural village populations is that they are static. A highly mobile population raises additional questions of time and concentration in respect to inputs. How long and for which periods were migrants exposed to the "beneficial" inputs; and obversely, what was the exposure outside of the "improved" village?

The population of each village in August 1976 was 1097 in Guanagazapa and 1006 in Florida. The populations under study were too small for any significance to be attached to the crude birth and death rates, infant mortality or vital index rates. However, the villages were comparable for demographic and vital statistics and for morbidity and mortality. There were differences in income, employment opportunities and land ownership.

Morbidity

Total as well as selected causes of morbidity were compared over seven periods of six-months each. The six-month periods were chosen to coincide with the rainy and dry seasons. Morbidity from all causes was

not significantly different in the two villages, though there was more total illness in the control village during the last eighteen months of the study. Over twenty types of illness were recorded, however, respiratory and diarrheal morbidity accounted for 70% of all the reported illness in both communities.

One study objective was to determine the effect of the sanitation inputs on diarrheal disease reduction and these data were examined in considerable detail. The results are comparable to those observed in other water/diarrheal disease studies. Children who were between one and two years old had more diarrheal disease than any other age group in the study. Children who were seven years of age and younger accounted for more than 80% of all diarrheal morbidity.

Diarrheal illness in the adult is low (< 20/1000/fortnight) and was probably under-reported, especially for mild episodes. However, on the basis of study data, one can state that diarrheal illness is not a significant cause of disability in these adult populations. The relationship between season and illness is also ambiguous when observed seasonally. However, the rates for diarrheal morbidity were higher for the rainy seasons ($p < .05$) when controlled for differences in sanitation and family size.

A review of the data on diarrheal morbidity leads to the conclusion that the introduction of water and the attempts to improve sanitation did not significantly affect diarrheal disease. Such a conclusion should not go unquestioned nor unchallenged. However, this conclusion derives from the study data and any questions must be directed to study methods The methods are discussed in detail in other reports[1]. Briefly stated,

---

[1] Final Report to Agency for International Development. Vol. 1 of the Food Wastage/Sanitation Cost-Benefit Methodology Project. UNC/INCAP, 1978.

morbidity surveys were performed by trained surveyors guided by explicit criteria, including the number and nature of bowel movement, for defining diarrhea. The survey was based on the respondants (usually the mother) recall of those diseases occurring in the family during a 15-day period prior to the visit. In order to validate the home visit record, a physician revisited 10% of the homes and separately arrived at a diagnosis for subsequent comparison with the surveyors record of the visit.

Mansourian, et al.[1] have discussed the difficulties of assessing research in which diarrheal disease is the affected variable. As in this study, such research is directed toward demonstrating associations between ameliorative inputs and diarrheal disease incidents. The definition of diarrhea may not be sufficiently operational for evaluating the impact of the inputs. The usual definition for diarrhea is based on the occurrence of more than three bowel movements per day as well as consideration of the characteristics of the fecal discharge. Diarrhea may be a manifestation of a symptom rather than a specific disease and the precipitating event is of less significance than the particular response of the affected individual. For the moment, there are still barriers to defining objective measures of normal defecation patterns, criteria for diarrheal activity and the elucidation of other pertinent relationships.

Improvements in Water Supply and Sanitation

Diarrheal morbidity leaves something to be desired as a criteria for the outcome of environmental improvements, however, it is "the only

---

[1] Mansourian, P.G., Sayers, B. Mc A., Newell, K.W. and Phan Tan, T., "A Pattern Analysis Study of Weaning Diarrheal Disease of Infants", International Jour. of Epidemiology 4(3): 173. 1975.

game in town". On the other side of the equation, water supply cannot be considered as a single point of reference, but as a part of a delivery chain. In fact, this chain for the delivery of water of high quality was difficult to maintain. The source and quality of the protected and treated spring water was excellent in the test village, however, there was subsequent quality deterioration in the household storage containers. The analysis, using Millipore Coli-Count Water Testers, of 698 samples from the test village distribution system showed that 97% of the samples had no coliform organisms. For comparison, only 48% of the 505 individual well water samples from the control village had no coliforms, while 41% of the water containers also showed no coliforms.

There were some expected findings in that the installation of a convenient and plentiful water supply system did promote water usage. When the study concluded, the families in the test village were using two and a half times the water per person than were the residents of the control village. How this additional water usage translates into maintaining a sanitary home environment is discussed later. The maintenance of a clean home environment is difficult under the conditions that existed in the villages and the homes. Water supply is not an isolated variable and problems in measuring desirable outcomes from water supply inputs may result from the neglect of providing a subsequent input of sanitation improvements and modification of health behavior.

Home Sanitation

Surveys were made throughout the period of the study to evaluate sanitary conditions in the home. It was assumed that the diarrheal diseases which were being recorded in the morbidity survey were mainly water-washed infections.

The chain of events for water-washed diseases starts with the water quality, but is mediated through greater or lesser availability of the water. The pay-off is improved sanitation and hygiene mediated through adoption of improved health behavior patterns. Sixteen sanitation criteria were chosen as representative of these improvements. These criteria included clothing cleanliness, food and utensil protection, house and yard cleanliness, presence of animals and insects, use of soap, and handwashing among others.

A health education program was conducted in the test village and nine criteria were examined over time (seasonally) to uncover any improvement in home sanitation practices. There appeared to be some improvement in (1) the use of wooden barriers to exclude animals from the kitchen; (2) the protection of cooked food; (3) the absence of garbage on the kitchen floor; and (4) the removal of trash and garbage from the yard. However, these tentative results were somewhat confounded by similar improvements in items (3) and (4) in Florida Aceituno. This is the control village where no health education program had been instituted.

Crowding in the home is considered an important contribution to morbidity. Continuous measurements of total home crowding and number of persons occupying each bedroom were made. The mean and standard deviation of respiratory illness and diarrheal disease rates were plotted against crowding in bedrooms and for total home area for both the villages. Morbidity rates did not increase with more persons per bedroom or more persons per household area.

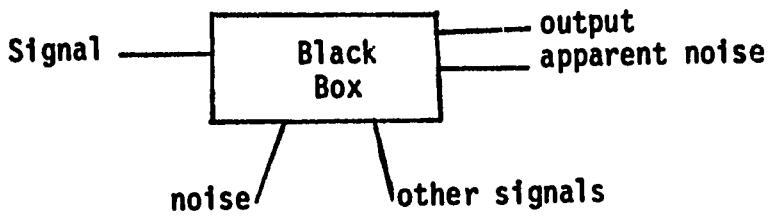
The data for census, morbidity and sanitation were examined extensively through the use of general linear and categorical models in order to determine if there were significant relationships between the four

types of morbidity (diarrhea, respiratory diseases, skin infections and other infectious diseases) and the range of measures on water and sanitation. These analyses were adjusted for age, sex, size of family, season and village. In this way, sanitation effects on morbidity could be estimated without being influenced by these other factors, which also influence morbidity.

The results of these comprehensive analyses are disappointing in respect to policy research but do emphasize that answers to the water/sanitation/health question are still not resolvable through field studies. The variables which were "controlled for" did have discernable effects on morbidity. In contrast, there was no single sanitation variable which had a measurable effect on the morbidity rate. This statement is striking since the results also show no significant relationship between water supply and the morbidity rates. Of course, the measurements were taken over a study period of less than four years; a relatively short period for change to occur.

There were a few trends showing limited degrees of change. For example, increased water consumption in the test village was associated with decreased diarrhea and skin infection in children aged 13-24 months. However, this association was so small that it is not possible to separate the signal from the noise. There was no significant difference in morbidity rates between the wet and dry seasons for skin infections or respiratory disease. However, morbidity rates were significantly higher for diarrheal disease during the wet season in both villages ($p < .05$). We feel that future studies in the water/health relationship must develop the measurement potential to deal with the multiple variables and the handling of patterns which must be separated and measured. The problem

may be stated graphically, as follows:



Thus, we may not be measuring the appropriate aspect of the variable.

It is not reasonable to conclude from these results that there is no association between sanitation and morbidity. After all, diarrheal disease and death, especially in children, are clearly a problem in the Less Developed Countries. The issue is only resolvable when reliable and pertinent measurement instruments are available.

Health Education and Level of Living

The provision of a piped water supply to the test village was supplemented by a program for community health development. The objective of the health education program was to reduce fecal contamination in the home and surrounding areas and to promote the use of the piped water supply. In specific terms, this component of the study was directed to:

1. persuading the villagers to reduce human and fecal wastes in the home and the surrounding areas.
2. installing barriers to keep domestic animals out of the kitchen.
3. promoting the installation and sanitary maintenance of latrines.
4. improving food and water handling.
5. increasing water consumption for hygenic purposes; particularly for home and kitchen cleanliness, food preparation, and handwashing.

It is difficult to evaluate the health education program since the operational period was only eighteen months. The test village did show

a post-program improvement in food and water storage and in handwashing. On the other hand, there were no changes in sanitation variables such as garbage disposal, cleanliness of clothing, and bathing. Pre and post program testing was done to assess changes in knowledge of health and sanitation. There was a clear indication of an increase in knowledge in the test village. However, to the extent that could be determined, there was no association between a change in knowledge and behavioral change as measured by improvements in household sanitation.

Level-of-Living Indexes

Another approach to measurement was through the evaluation of socio-economic and socio-cultural variables and their relationship to morbidity. The approach was through the use of a modification of Belcher's level-of-living index. The level-of-living of each of 400 households in the two villages was defined through a 20-item survey instrument in which the items were based on household functions and scaled according to the technological means employed in the accomplishment of the household function. Many of the chosen items represent sanitation facilities in the household.

Households were also characterized according to a scale of relative wealth status, occupational status of the head of the family, and levels of education and literacy of family members. Households were also described in terms of attitudinal modernity, cosmopoliteness, religion, and family size. Only family size was shown to be correlated with morbidity. Though the level-of-living scale does not seem to be an indicator of the family morbidity experience, it is useful in measuring socio-economic improvement at the rural household level. In any event, these socio-economic and socio-cultural measurements will have to be integrated with the physical and epidemiological measurements

that are currently used in evaluating health benefits from water supplies. Further details on water supply, sanitation and health education are presented in the next chapter.

III. Implications for Sanitation and Water Supply Programs in the Rural Areas of the L.D.C.'s

An advanced technology water treatment and distribution system was installed to supply a rural village in the lowlands of Guatemala. This system consisted of a protected source (spring), chlorination facilities, adequate storage and water mains with faucets in the yards of 164 homes. It was designed for health and environmental appropriateness but not for functional appropriateness as defined by Pacey[1]. This system provided high quality water (chemical and bacteriological), of unlimited quantity (but at a small cost), which was convenient and did not adversely affect the environment (breeding of vectors). However, it will be difficult for this village to adequately maintain this system without outside assistance in the future.

The primary purpose for installing this water system was to study the relationship of water to health, more specifically, to diarrheal morbidity and intestinal malabsorption. Functional appropriateness and cost were secondary considerations. The design and operation of the system met all the criteria for interrupting and/or reducing <u>water-borne diseases</u> (typhoid, cholera, amoebic and bacillary dysentery, gastroenteritis) and <u>water-washed diseases</u> (skin infections, otitis, conjunctivitis).

During the three year period after the installation of the water system, September 1973 to August 1976, the total morbidity of the population in this village was intensively investigated through monthly household surveys and a record of visits to the health post. No significant

---

[1] Pacey, Arnold (ed.), "Technology is Not Enough: The Provision and Maintenance of Appropriate Water Supplies". Aqua 1: 1-58. 1977.

changes in morbidity were observed (Table I).

TABLE I
Selected Annual Morbidity Rates in Guanagazapa

Disease	Incidence Per 1000 Population* 1973	1976
Total morbidity	123	124
Diarrhea	39.7	39.5
Respiratory disease	53.8	52.7
Skin infections	12.5	9.1
Conjunctivitis & Otitis	3.5	4.3

*Incidence computed on two-weeks recall experience in each month. The true incidence will be higher than this for an entire month.

Diarrhea, respiratory disease, skin infections, otitis and conjunctivitis were analyzed by age, sex, season (dry and rainy), water usage, and family size. Monthly family morbidity rates were preponderantly zero. Only family size was correlated with any of these diseases and large families (more than five persons) had a disproportionately high morbidity rate. Typhoid, cholera and schistosomiasis were not seen in this village during the study. No attempt was made to isolate the agent(s) of diarrhea, thus the prevalence of salmonella and shigella in the village population could not be estimated. Stool cultures were collected on a small sample of the population in 1973, 1974 and 1975. Approximately 5% of the cultures were positive for salmonella and/or shigella.

During the last eighteen months of the study, an intensive health education program was carried out in the experimental village. This program focused on improved personal hygiene, household sanitation, use of latrines and promoting water use. These additional efforts did not produce a measurable change in the morbidity of the village population.

This study was designed to assess the impact of water supply, sanitary education and a nutritional supplement. The plans for a nutritional component were dropped midway in the study. Neither the provision of a high quality, unlimited quantity of water (three years experience) nor intensive health education (eighteen months) reduced diarrheal or other morbidity during the period of the study. This finding has significance for future studies:

1. Providing water and water-use education to a village population, whose household environment is of poor quality (dirt floors, defective housing, poor food hygiene and inadequate personal hygiene), cannot be expected to reduce morbidity over the short term.

2. Providing water and a safe method for the disposal of human feces concurrently might be more effective than either alone. In the last year of the study there was a major program to promote the construction and use of latrines. This effort was successful insofar as construction of latrines; however, the study was terminated before the impact on diarrhea could be measured.

3. In a village with a higher diarrheal morbidity rate, particularly from those diseases which are usually water-borne, the combined impact of water and water-use education may have had a greater impact.

Some further details to amplify these statements are presented below.

Water Supply

It was apparent that "final-use" bacteriological water quality was inferior to source quality in both of the study villages. Even though 97% of the water samples collected from the distribution system in Guanagazapa were free of coliforms, only 65% of the samples collected from

home water containers were satisfactory. Water samples from shallow wells in Florida Aceituno were contaminated 52% of the time while home water containers were contaminated 59% of the time. These results have significant implications for future studies which attempt to correlate water quality with morbidity and they also indicate the increased risk to a population from contaminated water containers. Assuming that final-use quality (consumption, bathing, handwashing, dishwashing) is the same as source quality (distribution system or well) could lead to erroneous conclusions.

Human disease is related not to the quality of the water in the well or distribution system but to water used in the home or public establishment. Thus, it is the final-use water quality which should be monitored in any study attempting to relate water to morbidity. The bacteriological quality of water in home containers in these villages varied considerably over time. Water from the same container in the same home could be free of coliform bacteria one day and heavily contaminated the next day.

It appears that one of several approaches could be used to insure satisfactory final-use water quality:

(a) Install water faucets in the house which would eliminate the need for water containers. Even with the faucets in the yard, as installed in Guanagazapa; there was a considerable reduction in the number of home water containers.

(b) Provide intensive sanitary education to encourage daily cleaning and proper storage of water containers. This approach was not successful in this study (see Volume II, Results of the Field Studies, Tables V.1 and V.2, pages 94 and 95).

(c) Provide or encourage the purchase of water containers which can be easily cleaned and have a tight cover. This approach would also require extensive sanitary education.

Any study which purports to establish bacteriological water quality must collect samples at the point at which the water is used. Thus, the validity of the water quality data could be best established by selecting a small random sample of families in a community and monitoring their water quality frequently rather than selecting a larger sample which is monitored infrequently. If water is not further transported or stored in the home, use quality and source quality will usually be the same.

Sanitation

House construction and sixteen variables, indicative of sanitary behavior, were selected and monitored as indices of environmental quality (Volume II, Results of the Field Studies, pages 35-39). House construction and maintenance were surveyed annually and the sixteen environmental variables were monitored monthly. This array of variables is not exhaustive since it did not include information on food preparation practices, dishwashing, handwashing, infant feeding, the presence of insect vectors, and environmental quality outside the home (workplace, school, etc.). These latter variables are difficult and costly to quantify.

Studies, such as this one, would be vastly improved if it were possible to devise an environmental quality index (either numerical or descriptive) which could be shown to have a high positive correlation with diarrheal morbidity or health status. A feasible and practical index for field studies should contain as few criteria as possible, should be easily observed or measured, and should be as objective as possible. The use of this type of index would reduce the time and personnel required to document environmental quality.

Three different approaches were used retrospectively in an attempt to define such an index:

(a) General linear and categorical models were used to reveal any significant relationships between morbidity (diarrhea, respiratory disease, skin infections, conjunctivitis, otitis) and household sanitary quality. When characteristics, known to be associated with morbidity (age, sex, community, month, family size), were "controlled for" none of the sixteen environmental criteria could explain or were statistically associated with these types of morbidity. (See Volume II, Results of the Field Studies, pages 41-91).

(b) Three types of models (logical functions, statistical functions, mixed linear and power functions) were used to examine six independent variables which are usually considered to be associated with diarrheal morbidity (bedroom and total room crowding, source water quality, final-use water quality, protection of cooked food and water use). The "best model" (determined by the MAXR option of the SAS STEPWISE procedure) explained only 28.5% of the variance and it was concluded that these environmental variables alone or in combination could not explain diarrheal morbidity.

(c) The John C. Belcher level-of-living scale and a modification of this scale were used to test the hypothesis that the level-of-living of a household is a determinant of the morbidity experience of that household. The Belcher scale contains fourteen household functions: construction of walls, floor, roof; water storage; water source; lighting; food preservation; eating utensils; sewage disposal; type of transportation; cooking facilities; floor cleaning equipment; and dishwashing facilities. The conclusions from this analysis were that morbidity is

associated with level-of-living (environmental quality as defined by Belcher) but the association is weak and the level-of-living index is not a good predictor of the morbidity experience of a household. (Belcher, J.C. "A cross-cultural household level-of-living scale", Rural Sociology 37: 208 (1972) and the Ph.D. Dissertation, Jacques M. Faigenblum, Department of Environmental Sciences and Engineering, University of North Carolina, 1978).

These analyses confirmed what other investigators have reported. There is presently no single environmental defect or even a matrix of environmental defects that are clearly associated with diarrheal morbidity.

However, continued exposure to an unsanitary environment is presently equated with a significant increase in risk from diarrheal disease and other types of morbidity. Improving one or even several environmental deficiencies, including a piped water supply, may not result in a dramatic or perhaps measurable decrease in diarrhea. Health status might be improved by: (1) making substantial and simultaneous improvements in all aspects of environmental quality (housing, quality of the diet, solid and liquid waste removal, water quality and quantity), or (2) disregarding environmental quality and observing absolutely meticulous personal and family hygiene. This would require an abundant supply of potable water. Obviously, this latter alternative is less likely to be achieved.

Our data suggests that future studies, attempting to relate the environment and/or water to health, should attack this problem at the biological level. This would include the isolation and identification, if possible, of the responsible etiological agents, the source of the agent, and the transmission route. Attempting to relate environmental

quality directly to morbidity, specifically diarrheal disease, appears to be severely limited.

Health Education

The community health development approach used in this study was found to be practical and useful, particularly for small communities. Since the health education program was in effect for only one year, it was difficult to evaluate the potential impact which it might have had if it had been continued.

A health education scale was used to measure changes in attitude and perception after the initiation of the health education program. It was concluded that the program did influence the attitudes of the population relating to sanitation changes (See Volume II, Results of the Field Studies, pages 100-102). Whether these changes in attitude will continue is not known.

Several interesting observations were documented which have implications for future studies. Even with increased water availability and health education, the residents of Guanagazapa did not bathe more frequently nor did they wear clean clothing more often. However, they did report washing their hands more frequently. Handwashing and bathing practices were evaluated by questioning the female head-of-household and the validity of this data cannot be confirmed.

Improvement was documented in five environmental categories: removal of human and animal fecal matter from the home environment, protection of stored water, cleanliness of the yard, installation of latrines, and the exclusion of domestic animals from the kitchen and dining areas. These improvements, however, did not result in a decline in diarrheal or other morbidity during the study period. There are several possible

explanations for this. One, the improvements were not in effect long enough to cause a measurable decrease in diarrhea, or two, these environmental conditions do not contribute significantly as a source of diarrhea.

One technique which might be used for measuring the level of personal hygiene in future studies would be to quantify handwashing. A spot of silver nitrate, UV detectable fluorescent chemical, or a low intensity radioactive isotope could be placed on the hands of a sample from the population and its disappearance monitored. Two assumptions are made in this procedure. One, handwashing is a useful indicator of personal hygenic practices, and two, the disappearance of the applied substance can be correlated with the frequency of handwashing. This technique would have to be validated in a trial experiment and it would have to be culturally acceptable to the population.

A chastening finding was that attitudes toward health and sanitary improvements clearly changed in the experimental village as a result of the health education program but no association between attitudes and behavioral change was found.

IV. Summary of Results of the Study for Food Wastage

An important objective of the study was to design and test a methodology through which the relationship between the improved water supply and food wastage could be examined and described in economic terms. The linkages between water supply/diarrheal disease/malabsorption were not known at the initiation of the study.

The choice of intestinal malabsorption as a measure of the health benefits of water supply was based on the assumption that it would provide a convenient economic measure of the benefits in terms of the reduced costs of food wastage. However, there were major difficulties in dealing with intestinal malabsorption as a variable in this study. This syndrome had been previously investigated only in the clinical setting. This study was the first to treat with this condition on a population basis using community samples rather than individuals who were in a clinic setting. Further, the concept of a clinical standard defining malabsorption was shown to be untenable for population studies and the concept of a range of relative malabsorption for a given population was developed.

The role of malabsorption in diarrheal disease has been of interest in the last few years. Rosenberg, Solomons and Levin[1] reviewed the combined effects of nutrition and infection on the diarrheal diseases. They noted that, "more recently the concept of an enteritis-malabsorption-malnutrition cycle has been emphasized in which infant and child diarrhea leads to malabsorption, this in turn leads to malnutrition, rendering the

---

[1] Rosenberg, I.H., Solomons, N.W., Levin, D.M., "Interaction of Infection and Nutrition: Some Practical Concerns". Ecology of Food and Nutrition, 4:203, 1976.

host more susceptible to infectious disease". This study did not deal with malabsorption in the child because of cultural constraints in removing the child from the family for the six to eight days required for a balance study. The calculations of food wastage in the study did not include losses due to diarrheal episodes. Rather, the hypothesis was based on the potential for long term losses in the adult male. The adult malabsorption syndrome results from a continued trauma to the intestinal tract as a consequence of multiple bouts of diarrheal disease, particularly during the early lifetime of the individual. This hypothesis is reinforced by the following statement from the preceding article.

> "In some populations, 20-25 percent of the presumed healthy adult population demonstrated some defect in intestinal absorption when tested and although there are far fewer studies in children, there is growing evidence that tropical enteropathy is seen in the first few years of life. The true quantitative implications of this phenomenon in terms of nutrient and food wastage by malabsorption are still uncertain. However, the possibility that a large proportion of the population in less developed countries, who are already on marginal nutrient intake, are failing to derive nutritional benefit from that intake because of a chronic malabsorption problem underscores the difficulty of projecting nutrient requirements based on research under sheltered ward conditions in developed countries."

Malabsorption Studies

A basic objective of the study was to develop a methodology for assessing the extent of malabsorption in the village populations. There is a definite difference between clinical malabsorption and population malabsorption. From the clinical point of view, malabsorption is a syndrome representing the failure of the gastrointestinal tract to absorb food or nutrients due to a disorder or disease affecting that tract. If the degree of failure is severe, the diagnosis can be established both by clinical signs and laboratory tests. In sum, the clinical effect is the significant measurement.

When the degree of gastrointestinal failure is minimal or moderate (subclinical), then the detection and measurement becomes difficult. More important, it becomes necessary to define a quantitative limit for the "lower limit of normal absorption" and to establish criteria as to how such a reference value should be used. A detailed discussion of criteria and reference values for malabsorption is given in Vol. II of the project report (pp 140-147).

The derivation of costs which can be ascribed to food wastage requires the use of the concept of population malabsorption. The prevalence and extent of malabsorption in the community needs to be defined and established. Responses on a "yes" or "no" scale are not useful, as these would be in assessing the disease entity in the clinic. Further, the measure of absorption capacity must be explicit. For example, the term "50% absorption of all ingested calories" is directly interpretable in input-output terms for food wastage calculations. Clinical measures define malabsorption as "loss of fecal Nitrogen > 2 g./24 hr." The latter measurement is not useful for wastage calculations.

The requirement for input-output analysis leads to other measurement problems. First, separate tests are required to measure the absorption of the substrates in food (proteins, fats, calories). The measurement and integration of these variables is then required to define malabsorption, characterize absorptive capacity and provide for a food wastage calculation. Second, the extent of malabsorption in a given population must be defined relative to a reference point. The reference population for this study was a group of soldiers who were born in the Pacific lowlands of Guatemala and who had been living during the previous 18 to 24 months in a military installation near Guatemala City. The sanitation

status of the military barrack was better and the diet quantitatively superior to that available to the rural population in the test and control villages. Therefore, an appropriate reference population was chosen and the absorptive capacity of a sample of this reference population was measured. Malabsorption in the test and control villages was defined relative to the reference population. This reference population is an appropriate choice because they represent a level of sanitation and nutrition within a similar, though improved, mileu as compared to the rural village populations.

The progression from the measurement of intestinal malabsorption to the calculation of food wastage presented difficulties because of

the variable nature of biological events. First, it was necessary to deal with the digestibility of the diet regularly consumed by the villagers and the similar test diet to be ingested in the metabolic ward studies. The efficiency of digestion varies from one food to another. The diet regularly consumed in the rural Pacific lowlands is characterized by a high content of corn and beans and a minimal amount of food of animal origin. Information regarding the digestibility and biological value of this diet was fragmentary. Therefore, it was necessary to establish the relationship between amount of nutrient in the food ingested and the amount of nutrient which is excreted in the feces with this particular corn/bean diet. These studies were performed with the "reference" soldier population. The tests were done by adapting the soldiers to the rural metabolic corn and bean diet and performing balance studies for nutrient input-output over four balance periods. The mean absorptive values were then taken as the "normal intestinal absorption criteria" for calories, nitrogen, and fat for healthy young Guatemalan males. Actually, the lower third of the distribution curve, rather than the mean,

was chosen as "normal". The criteria selected as the lower limit of "normality" were 90.5% for the absorption of calories, 82.5% for the absorption of nitrogen and 83.5% for the absorption of fat. These are more realistic criteria for the absorption of calories, nitrogen and fat for a population on a rural Guatemala diet than the currently available "norms" which are more applicable to North American and Western European diets.

The resolution of one question led to other questions.

The digestibility study provided the information for an operational definition of absorption for comparison with subjects living in the lowlands of Guatemala. The experimental design of the digestibility studies provided an estimate of the variability of absorption including subject-to-subject variability, and variability within an individual from one balance to another. Briefly stated, intake of nitrogen and calories in the subjects was controlled over six balance periods. In contrast, fecal excretion of nitrogen, calories and fat fluctuated among individuals and from balance to balance, although stabilizing somewhat in the last four balance periods. A more surprising finding was the wide fluctuation in fecal calorie excretion within the same subject from one balance period to another. These observations of the inherent variability of a biological process should be recognized and taken into consideration. However, these fluctuations do not invalidate the concept or operational use of the absorption "criteria" derived from the measurement of the reference population. One cannot study humans without encountering variability. This variability was also seen in the studies on intestinal malabsorption in the village populations. Prior to the study it was assumed that a subject's absorption over the four years of the absorption studies would be highly correlated. That is, a "malabsorber"

in 1973 would probably remain a "malabsorber" and a "hyerabsorber" would continue as such if conditions stayed the same in the home and the village. This study has changed that view since individual absorption is not highly correlated from year to year.

Absorption Studies in the Village Populations

The balance studies were performed over four years (1973-76) and participants were chosen from a pool (longitudinal sample) of adult males (15 years and older). Sixty participants from each village (120 a year) were subjected to the balance tests once per year for a period of at least six days. The tests were performed in a specially designed facility located midway between the two villages. The longitudinal sample was relatively stable in that 45 men from Guanagazapa and 37 men from Florida Aceituno participated in all four years of the study. Replacements for dropouts came from the original pool of 97 men in Guanagazapa and 98 men in Florida.

The data from these studies is voluminous and cannot be dealt with in any detail in this summary. Some selected examples have been chosen to illustrate the results obtained. Table VII.6* illustrates the Percentage Absorption of Nitrogen (Four Years of Absorption Studies for All Subjects). There were two sequential balances for each subject for the years 1974 through 1976. The mean percent absorption of nitrogen and calories was uniformly lower in the second balance each year even though the diet, test protocols and schedules were identical. This variation has not been explained and is one of the unknowns connected with the measurement of intestinal malabsorption to be discussed in a succeeding section.

---

*Tables are from Volume II of the final report on the project.

TABLE VII.6

Summary of Four Years of Detailed Absorption Studies For Percentage Absorption of Nitrogen For All Metabolic Ward Participants

Year and Balance	FLORIDA ACEITUNO (FA)		GUANAGAZAPA (GU)		Average: FA & GU		Difference: GU - FA			
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	t	sig
73	74.1597	1.05452	77.09	1.03557	75.6248	0.739405	2.93034	1.47715	1.98378	0.0476192
74A	77.0233	1.01041	78.9227	1.0191	77.973	0.718668	1.89936	1.43285	1.32558	0.185353
74B	71.9497	1.01929	75.5478	1.02777	73.7487	0.724981	3.59818	1.44505	2.49001	0.012974
75A	79.0876	1.01229	81.0528	1.02918	80.0702	0.724052	1.96518	1.43906	1.36557	0.172454
75B	75.5729	1.01232	76.5998	1.02025	76.0864	0.720912	1.02688	1.43286	0.716667	0.473787
76A	77.4665	1.02249	84.5594	1.01372	81.0129	0.723389	7.09288	1.43295	4.9502	9.02852E-07
76B	76.9422	1.03221	83.8729	1.01375	80.4075	0.727198	6.93069	1.43911	4.81594	.0000017496
73	74.1597	1.05452	77.09	1.03557	75.6248	0.739405	2.93034	1.47715	1.98378	0.0476192
74Avg	74.4865	0.718795	77.2353	0.724852	75.8609	0.512069	2.74877	1.0175	2.70151	0.0070474
75Avg	77.3303	0.718201	78.8263	0.726652	78.0783	0.51397	1.49601	1.01539	1.47334	0.141049
76Avg	77.2043	0.730352	84.2161	0.720216	80.7102	0.517978	7.01178	1.0154	6.90541	0

	Florida Aceituno (FA)				Guanagazapa (GU)			
	Mean	S.E.	t	sig	Mean	S.E.	t	sig
76-73	3.04468	1.27943	2.37972	0.017557	7.12612	1.25899	5.66019	2.1009E-08
76-74	2.71784	1.01864	2.66811	0.007781	6.98086	1.01619	6.86964	0
76-75	-0.125941	1.01565	-0.124	0.901346	5.38983	1.0156	5.30704	1.4408E-07

	Average: FA & GU				Difference: GU - FA			
	Mean	S.E.	t	sig	Mean	S.E.	t	sig
76-73	5.0854	0.898761	5.65824	2.1240E-08	4.08144	1.79245	2.27702	0.0230462
76-74	4.84935	0.720105	6.73423	0	4.26301	1.43748	2.96562	0.00310974
76-75	2.63194	0.718334	3.66396	0.00026457	5.51577	1.43596	3.84118	0.000132045

NOTE: These results are adjusted to an average age of 26 years. 10 months. All significance levels are based upon a linear model for which s^2 = 61.0737 with 807 degrees of freedom.

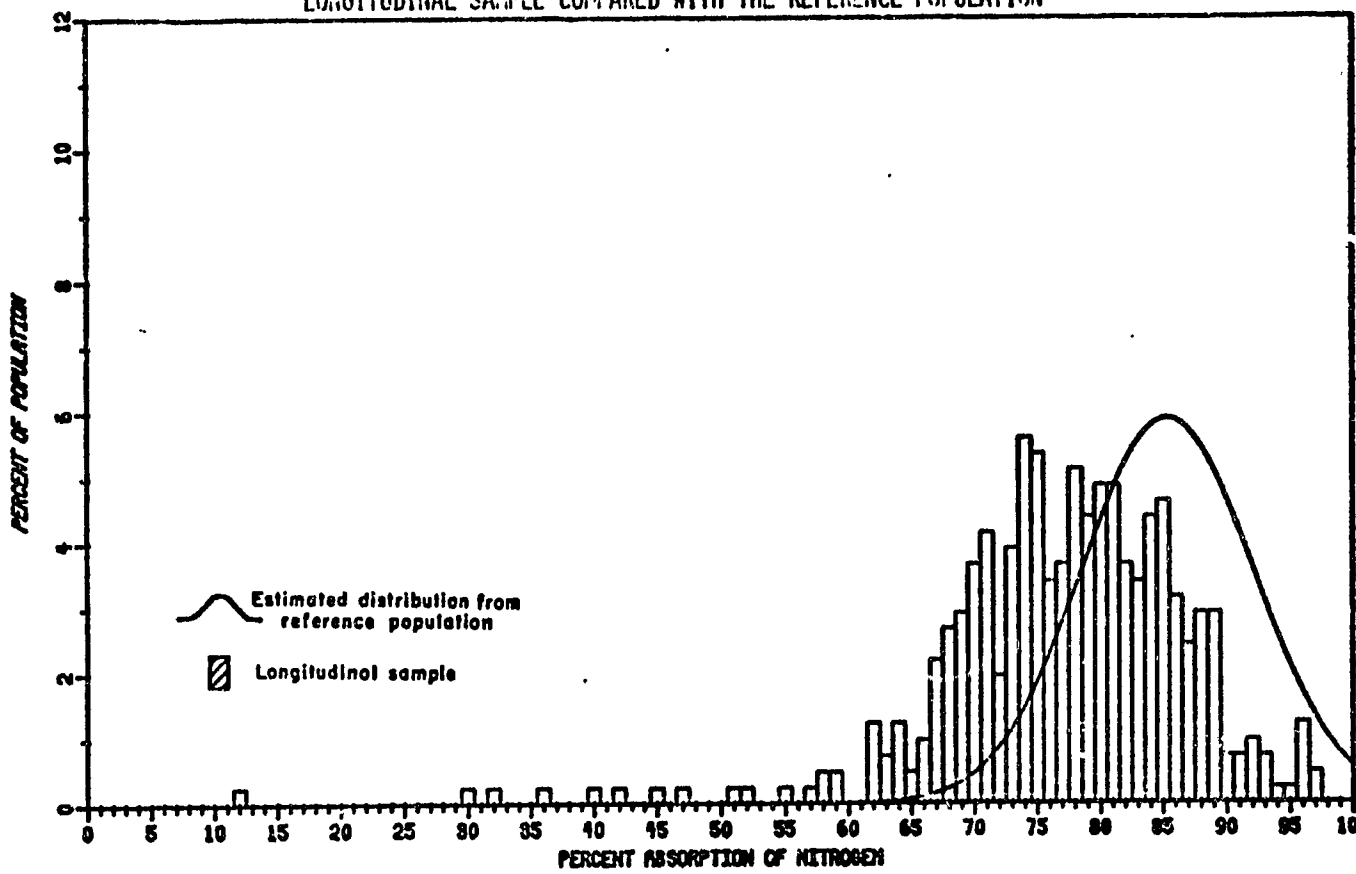
The histogram format was used to illustrate the comparisons between the village malabsorption studies and the results from the "reference" population of Guatemalan soldiers from the Mariscal Zavala army post who were extensively studied in 1974. Specifically, Histograms VII.1 and VII.2 show the "Distribution of Percentage Absorption of Nitrogen in the 1973-76 Florida Aceituno (and Guanagazapa) Longitudinal Sample Compared With the Reference Population". An inspection of the histograms shows that the mean absorption of the "reference" population was more efficient than that of the villagers.

In respect to the specific food components, Guanagazapa subjects showed an increase in the absorption of nitrogen from 1974 through 1976, when first and second "balance effects" are averaged. For calories, the longitudinal sample population from Guanagazapa showed a slight increase over the four year period while the Florida Aceituno results were characterized by fluctuations over the same period. An improvement in the efficiency of absorption can not be predicted from comparisons between the test and control villages until the underlying biological mechanisms and validity of the test procedures are further elucidated. Some of these problems are discussed later in this report.

The results for the absorption of fat are mixed. The Guanagazapa subjects had a high level of fat absorption in 1973 which dropped in 1974 and returned to the initial level in the last two test years. The Florida Aceituno population were at a low level in the initial year and the percentage of fat absorption increased to approximately the same level as the Guanagazapa subjects by 1976. A constraint on the interpretation of the results, which also holds for other components of the diet, is the short period of testing and the variability of the results.

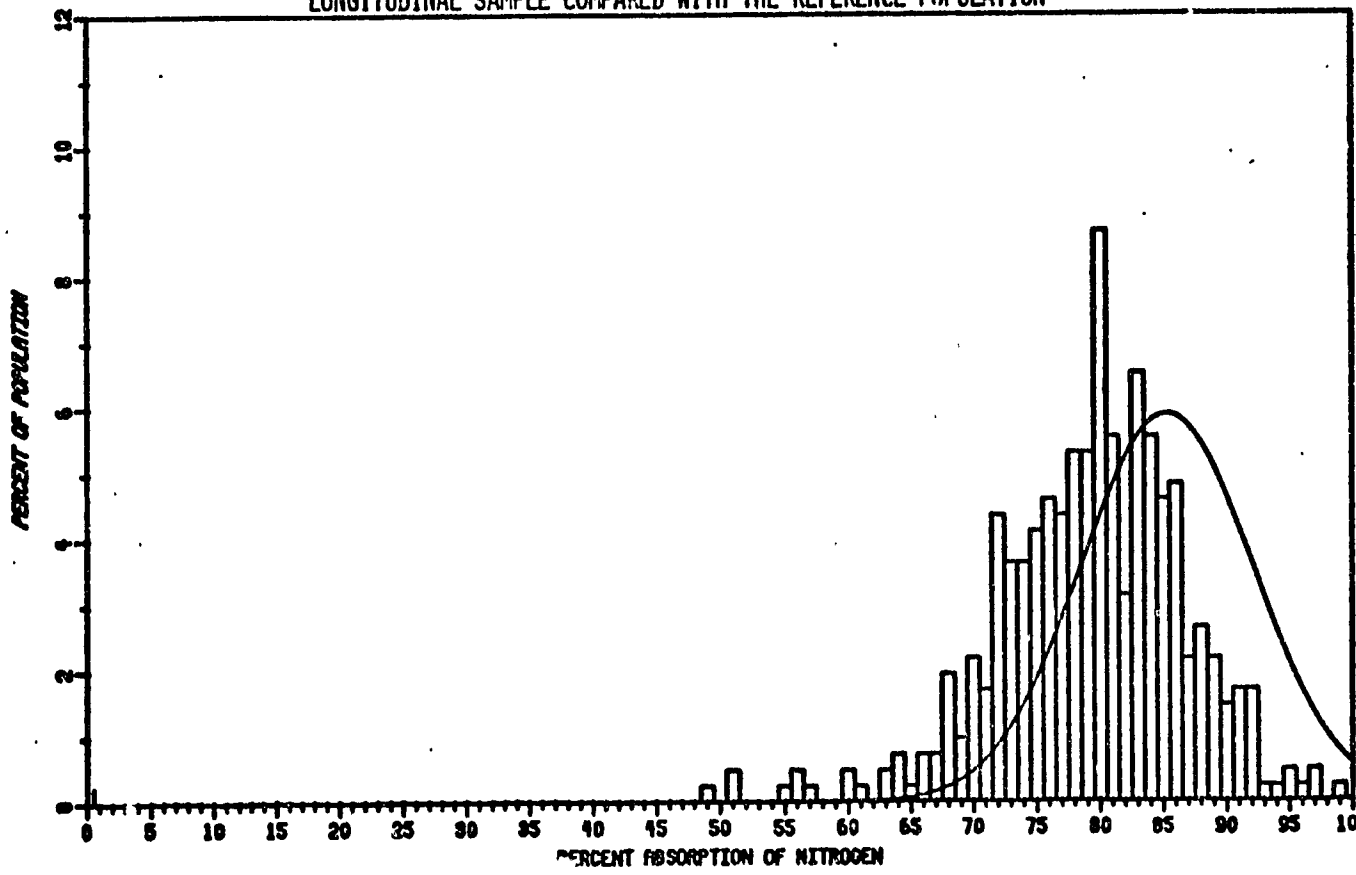
HISTOGRAM VII.1

DISTRIBUTION OF PERCENTAGE ABSORPTION OF NITROGEN IN THE 1973-76 FLORIDA ACEITUNO LONGITUDINAL SAMPLE COMPARED WITH THE REFERENCE POPULATION



HISTOGRAM VII.2

DISTRIBUTION OF PERCENTAGE ABSORPTION OF NITROGEN IN THE 1973-76 GUANAGAZAPA LONGITUDINAL SAMPLE COMPARED WITH THE REFERENCE POPULATION



Four years is too short to sufficiently express a trend or to expect a change in the complex biological mechanisms which determine improvement in intestinal absorption.

A large sub-set of the sample remained in the test for each year during all four years of balance studies. These subjects show essentially the same patterns as seen in the results for all the subjects in the balance studies. This result is expected since this "longitudinal sample" of subjects actually makes up the majority of the total subjects who comprise the data base for each years study. It is interesting to note that correlation studies over successive years for the group of subjects who remained through the entire study shows that there is some consistency in the group percent absorption of nitrogen, calories and fat from year to year. However, for the individual, knowledge of a subjects absorptive capacity in one year provides little information on the subjects capacity for the following years.

The results of these input-output balance studies of intestinal efficiency must be evaluated with regard to the uncertainties of scientific knowledge about intestinal absorption. It is now evident that four years of field trials are not sufficient to measure the social and biological changes which might lead to an improved absorption status. Further, the relationship between malabsorption and water supply will not be demonstrable until more information is developed on the linkages between water supply, diarrheal disease and population malabsorption.

Food Wastage

In the simplest view, the balance studies represent input minus output. However, such straightforward calculations are the end result of complex physiological events and , in some cases, pathological processes.

The input, i.e. the diet consumed by the balance test subjects, was controlled through the use of the 2800 Kcal/day rural diet. The variation in the quantity of food intake in terms of calories may affect the output in other than a direct relationship. In this case, the utilization of calories would vary with the caloric content of the diet, as well as with the efficiency of absorption. For instance, starved animals absorb more efficiently than well-fed animals.

The change in absorption efficiency between the first and second balance period (sequential) presents questions. The study procedure for 1975 and 1976 called for the beginning of Balance I on Day 1 and ending on Day 4. Balance II was started on Day 4 and ended on Day 7. The percentage absorption of nitrogen and calories was consistently less for Balance II than in Balance I.

The relationship of diarrhea to malabsorption is clear. There is a definite and sometimes extensive food wastage during diarrheal episodes. Food losses due to diarrhea were not measured in this study, although these events are significant in relation to the nutrition-infection interaction, especially in children. However, the acute loss due to diarrhea does not appear to be significant in calculating economic losses due to food wastage. The acute incident is time-limited and the interest of the study was in long term continuing, and perhaps, lifetime effects. The highest prevalence of diarrheal disease was in children less than five years old. Indeed, our study and others show that the adult in the less developed countries is not the continual victim of diarrheal disease. Cvetanovic and Grab[1] note,

> For example, in diarrhea the incidence in infants and young children is important while diarrhea in adults is rather rare.

---

[1] Cvetanovic, B. and Grab, B., "Rough Determination of the Cost-Benefit Balance Point of Sanitation Programmers", Bulletin of the World Health Organization, 54:214, 1976.

> In such a case; sanitation covering young age groups, e.g. at home and in school, would be more beneficial and would be more likely to fall on the benefit side of the balance line than sanitation among older groups.

This confirmed finding on child morbidity leads to a question as to why the study restricted the absorption studies to adult males. At the first level of response, women and children were barred from the ward studies because of cultural constraints. More important, the study of the adult was clearly required by the experimental design. The hypothesis was that the repeated attacks of diarrhea in childhood lead to an enteropathy which persists through adult life and results in a lowering of intestinal efficiency through life. If this is so, the individual food waste losses may be small; however, these may be of economic consequence when aggregated over the lifetime and in populations. A further hypothesis was that population malabsorption is reversible through improved sanitation and personal hygiene. It should be noted that all subjects chosen for balance studies were given a medical examination before testing. Any subjects who became ill, particularly those showing diarrhea, were removed from the test.

The problems in defining and establishing reference criteria for population malabsorption have been discussed. There are further problems with measurement and particularly in measuring the small differences in intestinal efficiency which may characterize population malabsorption. We have noted the reduced efficiency which was a consistent finding for the second balance period. This may be due to adaption to the diet used in the metabolic ward, a lack of activity, and decreases in the number of bowel movements.

Economic Losses from Food Wastages

What can be said about the economics of food wastage? Since the constant differences between Balance I and II in the same individual cannot be explained in physiological terms, the results were averaged. Using the average, subjects from Florida Aceituno (control) and Guanagazapa (test) show a slight increase in population intestinal efficiency over the four years of study. The increased efficiency from Guanagazapa for the fourth year is statistically significant. However, there are problems in data management for this fourth year which are discussed in Vol. II of the final report (p. 156)*.

The project investigators at UNC-CH and INCAP agree that these data do not indicate that there was a real change in intestinal efficiency in Guanagazapa that could be interpreted as significant for the economic calculation of food wastage. There are a number of reasons:

1.) The four year period was not sufficient time for evaluation.

2.) There was significant variability within the same individual from year to year.

3.) This study has expanded the understanding of some of the biological linkages between diarrheal morbidity and malabsorption, however, the primary linkages have not been clarified. For example:

Hypothesis A. Repeated diarrheal disease in childhood leads to enteropathy which in turn results in chronic population malabsorption and food wastage. There was not enough time to test this hypothesis. All that can be said is that there were no striking decreases in infant and childhood morbidity. However, there are problems in measuring morbidity which are discussed in a separate section of the report.

Hypothesis B. The enteropathy discussed in A. above is reversible

*The 1976 absorption data is being evaluated and an addendum to the report will be issued in October 1978.

through improved water supply, sanitation and personal hygiene. The length of the intervention was not long, ranging from four years for water supply to one year for hygiene behavior modification. The changes observed in improved intestinal efficiency were in the right direction although there were no significant changes in diarrheal morbidity. There was an increased use of water in the test village which is an acceptable indicator for potential sanitation change.

In sum, these results do contribute to the scientific understanding of intestinal absorption and food wastage. However, these results do not fulfill the needs of policy research in providing a clear basis for planning, and particularly, for resource allocation. There is, however, sufficient reason to believe that the phenomenon of population malabsorption is real when evaluated by reference to a comparable population living under improved sanitation conditions.

V. Implications for Future Studies

In January 1976, the International Bank for Reconstruction and Development issued the report of a 1975 meeting of an Expert Panel on the "Measurement of the Health Benefits of Investments in Water Supply[1]". The report represents a focal point in the shift to a new paradigm in water research which recognizes there are methodological questions still to be resolved before effective health benefit studies can be fruitfully undertaken. The panel concluded that the benefits could not be quantified given the present state of knowledge and that studies to establish a rigorous relationship between water supply and health would be extremely expensive and their conclusions would be of doubtful application.

It is useful to point to the discussions of the expert panel on the "Methodology of Measurement and Indices" and compare their comments with the actual field measurement experiences of the UNC/INCAP study:

The I.B.R.D. report notes that water-related diseases and conditions can be assessed by a limited number of procedures:

1.) Diarrheal history of infants by questionnaire or survey

2.) Fecal inspection and examination for bacteria and parasites

3.) Clinical examination, especially of skin and eyes

4.) Observation of physical development and the nutritional status of children

---

[1] I.B.R.D. - I.D.A., Measurement of the Health Benefits of Investments in Water Supply. Report of an Expert Panel to the International Bank for Reconstruction and Development (May 5-7, 1975). Public Utilities Dept. Note Series, January 1976.

5.) Observation of the state of personal hygiene and the sanitary condition of dwellings.

Procedures 1 and 5 were used in the assessment of morbidity and sanitation in this study. The morbidity survey had two components. The house visit survey was based on the respondents recall of those diseases occurring in the family during a period of 15 days prior to the visit. As with all recall procedures, there are ample opportunities for misinterpretation and unreliable responses. However, the survey was performed consistently over the length of the study and reached all families to provide a comprehensive sampling of disease in the community. Indeed, for morbidity assessment, the survey may be the only practical method. These house visits were supplemented by careful recording of all morbidity observed at the health post in both villages.

The accuracy of morbidity measurements, particularly with respect to diarrheal and respiratory diseases, in a free-living population has not been validated. The general approach (including the current study) has been to establish and document a methodology, collect the information, and to collate the data with reference to the method used. This approach does not establish the validity nor precision of the method used. However, as was done in this study, the validity of the data can be improved somewhat by having a clinician revisit a subset of the population on a regular basis. This approach to collecting morbidity data can be useful in establishing trends and detecting epidemic outbreaks but it has not been sufficiently validated for measuring long term endemic levels of morbidity.

In any study in which morbidity rates are the dependent variable and the detection of small changes are significant, it is our opinion that a clinical approach is necessary for accurate measurements. Thus,

a randomly selected subset of the free-living population would be chosen which could be conveniently visited by a clinician (physician) either daily or every few days to measure incidence or less frequently to measure point prevalence (taking into account seasonality, cultural mores and any previous disease data which may be available). This physical examination of individuals in the sample should be supplemented with specimen collection where indicated. This approach is not unique and is patterned after classical clinical diagnosis, however, it would be severely limited by time and economic considerations.

The forms and protocols for the house visit morbidity assessment* had been used by INCAP for almost 25 years but there were some problems in applying the method to the study. There were reservations as to the need for such comprehensive coverage of the population and the inclusion of multiple disease entities. These reservations, which only arose after the survey method was actually tested, included:

1.) The survey was directed to morbidity in children and adults. Future surveys should be limited to children since the incidence of diarrhea is small in adults. Further, responses for the adult are less reliable than for children. The mother is the usual respondent and has good knowledge of the health status of her children. This knowledge does not extend to the rest of the family, particularly the adult members of the family. Also, perceptions of what an adult will consider diarrhea will vary, despite a definite criteria for the number of bowel movements.

2.) The monthly population survey for morbidity required the enumeration of the monthly population base in the villages. A rather elaborate

---

*The detailed methodology for the UNC/INCAP study is presented in Volume 1 of the project report.

census survey was done monthly. This census required a complex data management system. The census was worthwhile since it recorded the unexpected mobility of the population. However, the census-morbidity protocol needs to be simplified while still maintaining an acceptable degree of reliability.

3.) The disease classification for the morbidity survey and for the health post visits was based on disease and symptoms for the 10 body systems. The assessment, therefore, was for a complete recording of any deviation from normal health status. However, the primary interest of the study was in the diarrheal disease complex. It is fair to ask, if the morbidity survey was too comprehensive for the purposes of the study. Also, the need to question and recall a variety of diseases and symptoms may have detracted from the specific recall of diarrheal incidents by the respondent.

4.) The health post data was recorded by nurses and physicians for villagers who came to the health post for treatment. These data, therefore, represent clinical evaluations. The health post findings may supplement the home morbidity surveys and should provide a valuable adjunct to those findings.

5.) Microbiological examination of feces for shigella-salmonella was limited to obtaining monthly rectal swab samples from a cohort of 20 children (1 to 4 years) in each community. An additional group of thirty children were randomly chosen each January and July. The prevalence of shigella-salmonella was monitored through this index sample of children. It is difficult to say if a more comprehensive program of microbiological sampling would have been useful. A number of studies on children, where such stool samples were taken, have shown only 4 to 33% incidence of "pathogenic" bacteria. New studies would have to include an examination for

viruses, including the rotavirus.

Parasitology surveys were scheduled for the beginning and final stages of the field studies. Two surveys (1972, 1973), covering 55 to 60% of the village populations (500-600 samples per community), were completed. The sudden termination of the project did not permit the scheduling of the final survey.

6.) Anthropometry surveys were done in 1972 and 1973 on 70 to 75% of the village populations. In retrospect, it may have been more efficient to limit these studies to children. However, special efforts were made to recruit families with small children for the anthropometry studies. The final anthropometry survey could not be done because of the termination of the project. The anthropometric data for children giving comparison, over time, of weight, height, arm circumference, head circumference and tricipital skinfold are valuable sources of information. However, their value in this study is limited because of the lack of reference anthropometry data for comparison.

7.) There have been extensive discussions in the literature on the methods for morbidity surveys. However, much less attention is given to sanitation and personal hygiene surveys. The sanitation surveys in this study were performed in considerable depth and detail. The evaluations included physical measurements of water quality, water consumption, housing, crowding, and the availability of sanitary facilities. In addition, aspects of sanitation behavior were assessed to a greater extent than in other studies. Further, trained practitioners in health education and socio-cultural measurement performed surveys on personal hygiene, level-of-living and economic status. There is sufficient evidence to propose

that sanitation measurements as performed currently are not adequate for detecting the actual changes that determine the effects on morbidity. Particularly, the current techniques do not measure the changes that are determined by the concordance of multiple variables that interact in the water supply/health benefits relationship. The over-riding variable is probably time. The ameliorative inputs of the study should be operational for at least five years.

The I.B.R.D. report on "Measurement of the Health Benefits of Investments in Water Supply" recognized the multi-variate aspect of the problem, by noting,

> Evaluation of selected other relevant variables is crucial, firstly to attempt to ensure that extraneous factors do not invalidate ascribing the health differences between project and control area to the water improvements; aspects in which the project and control area appear to differ significantly need particular attention. Secondly, knowledge of the effect of related environmental, social and cultural variables is also likely to prove of great value in attempting to maximize the benefits from any given water supply installation.

A review of this project's design and results has indicated that the so called "extraneous" factors are as important as the measurement of sanitation status. Indeed, these "other relevant variables" may be those which ultimately determine the contribution of the water supply to health benefits. Future studies should be built on an appreciation of the linkages of variables. This is an appreciable task considering that there is still an information gap in understanding and measuring the etiological determinants of water-related disease. The biological basis for diarrheal disease needs to be linked to the physical determinants of change, including water supply and sanitation facilities. However, these physical modifications do not become effective till they are used. Such use is determined by patterns of personal and group behavior, as well as

the influence of economic and social factors. The linkages are more difficult to define in the progression from the physical factors to personal behavior and community factors. The changes in personal and community behavior are established over extensive time periods and few experiments are conducted over a sufficiently long term.

VI. Other Relevant Variables

There was an attempt to account for other variables in addition to morbidity and sanitation in the study. These other relevant variables are discussed below.

Health Education

The specific objectives of the health education component of the study were to:

1.) reduce the fecal wastes of animal and human origin which were present in the home and surrounding yard

2.) assist families to install gates to keep domestic animals out of the kitchen and home

3.) promote the construction and use of latrines

4.) improve food and water storage practices

5.) increase water use for hygenic purposes; as in home and kitchen cleanliness, sanitary food handling and handwashing

The details of the health education methodology and results are presented in Vol. II of the report titled "Results of the Field Studies". One approach to measurement was by comparing actual changes in sanitation variables in a village over time and the extent of the change between the test and control villages. For instance, the clothing worn in the control village was judged to be cleaner than in the test village. It was anticipated that the availability of the clean, abundant water supply would lead to a marked improvement of the cleanliness of clothes worn by the respondent (usually, the female head of household). Instead, the homekeepers of Guanagazapa switched their clothes-washing from the

river or the community Pila to the home. Women reported that they washed clothes more frequently, but in smaller quantities. Therefore, there was no over-all change in the cleanliness of their clothing. There were improvements in hygiene behavior in the test village. There were improved trends for covering cooked foods and reduction of fecal matter on the floors in the Guanagazapa homes. Kitchen hygiene and water storage had been stressed in the womens' programs.

The assumption of the health education program was that the villagers in the test village would acquire new attitudes relating to sanitation behavior which would lead to actual changes in their sanitation practices. A longitudinal sample of families in both villages was interviewed in 1975 and 1976. A sanitation perception scale was developed for these surveys, which were directed to the female head of household. This scale was used to measure attitudes and perceptions of hygiene and sanitation. The survey included questions on perceived differences between potable and non-potable water, attitudes toward human feces, and knowledge and beliefs about diarrheal disease. The respondents in the test village showed significantly more modern and informed perceptions of sanitation than those in the control village. The only observation that can be made about this aspect of the health education program is that information did reach the residents of the test village. The translation of these measured changes in perception and attitude into actual behavior was not demonstrated in this study. The linkage between knowing, believing and acting is one that practitioners of the "harder" sciences do not wish to deal with. However, future studies in benefits of water supply cannot ignore these "soft" variables.

Results of the evaluation of sanitary practices in the villages

showed that control village and test village women did not differ in the number of times per month that they bathed. The test village women did have a preference for their potable water supply over untreated sources and they felt that the potable water was "cleaner". Also, there was a significant improvement in handwashing behavior as reported by the respondents in the test village.

A latrine construction program was started in the test village. In the period between May 1975 to August 1976, seventy-nine new latrines were installed compared to none in the control village. Most materials and instructions were provided with the householder providing the labor and paying some of the material costs. This effort was accomplished through the work of a Village Betterment Committee, one of several men's and women's committees organized as part of the community development program. Visits to the village in 1977, after the termination of the project, confirmed that the latrines were still being used and maintained adequately. Only one family had stopped using their latrine.

The health education program was designed to change sanitation behavior in order to optimize the benefits from the potable water system. Therefore, the program was considered as an integral input to the sanitation improvement effort. Attitudes toward health practices and use of the sanitation facilities clearly were changed as a result of the program. However, no association was found between the attitude change and the subsequent change in sanitation practice when data from the various surveys were correlated.

The health education program component of the study seems to have been well-conceived and performed. Yet, the program did need more resources and had only a short time for implementation. Programs for behavior modification can only be judged over the long term.

Dietary Influences

Dietary and food consumption surveys were performed regularly to meet several study objectives, including:

1.) defining the dietary intake of the village populations. The purpose for these surveys was to evaluate the nutritional status of individuals and groups; to determine dietary habits; and to gather detailed information about the quality and quantity of food consumed by the village population. Another purpose was to establish a basis for the diet to be used at the metabolic ward in the intestinal absorption studies.

2.) monitoring the variations in food intake over time in each village and for comparisons between the villages.

3.) monitoring the cost of food items in the local markets as a basis for calculations of the cost of food wastage.

There now exists an extensive data set for dietary information, which is a valuable resource. For instance, we were made aware of a change in the diet during a year when there were food shortages and inflation. However, data from these surveys require extensive processing

Economic Analysis

Oneobjective of the study was to develop a method for measuring food wastage due to intestinal malabsorption and expressing this loss in terms of food costs. This, of course, is a limited objective in terms of economic analysis. A more comprehensive hypothesis for economic analysis could be expressed as follows:

1.) Diarrheal morbidity leads to diminished productivity in termsof hours worked, money earned, and absenteeism as well as other measures of

economic productivity. Illness also imposes direct medical costs without considering the intangible costs of illness and discomfort.

2.) Food wastage is additive to diarrheal morbidity in that intestinal malabsorption leads to losses in energy and nutrients. These losses, by themselves, and in combination with diarrheal morbidity may, in turn, lead to diminished economic productivity.

There was an attempt to conduct an economic analysis for productivity in the early stages of the project. The economic studies were initiated in April 1973 and terminated in September 1974 on the recommendation of an external review committee convened by A.I.D. This recommendation was based on the need for extensive additional resources, both in personnel and money, to continue the economic surveys. These additional resources were not available to the project.

The economic studies that were initiated were based on three indicators measured in a sample of the village populations. These indicators included total hours worked per fortnight, gross individual income per fortnight, and days of "no economic activity". The indicators were further related to three group characteristics which may produce differences in the mean values of the above stated economic indicators. These characteristics were age, family position and occupation. The employment activity characteristics over selected months were also studied with reference to salaried employment versus self-employment, and between the agricultural and non-agricultural sectors.

The economic data was limited in scope and based on a small sample over fourteen months. The data is not sufficient for economic analysis, however, the information was useful in comparing the economic characteristics of the two villages.

The cost of the piped water supply to Guanagazapa came to Q55,029 (the quetzal is equivalent to the $ U.S.), not including the planning, engineering and design costs for the project which were incurred by the Guatemalan Ministry of Public Works. Annual costs for maintenance of the system and estimated income from water charges have also been calculated. A simple approach to the economic analysis would be to calculate the losses due to food wastage and compare these to the water system costs after discounting. This approach may be simplistic because it does not account for other benefits deriving from a piped water supply. If the malabsorption syndrome can be reversed through the provision of safe and abundant water supplies, then the food losses averted for the individual could be aggregated into economic benefits at the community level. The calculations are neither simple nor simplistic since there are underlying complexities which are discussed below.

The biological explanation for the assumed relationship between repeated diarrheal disease in the child and subsequent chronic malabsorption in the adult population has not been established. There is sufficient reason to believe that this enteropathy does exist in the hot and economically depressed areas of the world. Further, this study has gone a long way toward demonstrating that "population" malabsorption exists in a specified population. Therefore, the concept of economic food wastage is tenable. The further question relates to the extent of the economic losses that may be attributed to the condition.

Calculation of Food Wastage

There are several caveats that limit our ability to measure food wastage. This study dealt with a population who were not clinically ill and who were in a specific geographical and cultural setting. The

measurements were designed to determine "subtle" rather than overt clinical changes. The subtle changes then had to be compared with a "normal" value which was derived from the study of a similar population free from repeated diarrheal disease for a sufficient period to allow for improvement in gastrointestinal tract efficiency.

The cycle of studies involved:

1.) establishment of the absorption test methods, including the selection of the rural metabolic diet and metabolic ward procedures, laboratory procedures and the choice of the longitudinal sample.

2.) determining the digestibility of the diet.

3.) conducting the intestinal absorption study.

4.) food cost studies. These surveys were done in each month of the study to determine the cost of foods most commonly eaten by the village populations. The price information was based on the local markets in the communities and in Esquintla.

5.) calculating the cost of food wastage.

The calculation of population malabsorption was derived from the differences between the two population means (reference and village). The amount of calories, nitrogen, and fat lost in the stools was calculated from the difference between the average percentage absorption of individuals in the village longitudinal sample and the average percentage absorption of the reference group of soldiers. The extent of food wastage was assumed to be the difference between the stool loss of the average villager and an average soldier from the reference group. This average percentage loss of absorption (per person per day) was then applied to the daily food intake to derive the amount of food lost (per

person per day).

Since both the villagers and the reference group consumed the same diet, there was no need to discount for differences in diet digestibility. However, it should be noted that the absorption of food is a dynamic and complex process that may vary depending on the interaction between the environment, characteristics of the human subject (such as health status, gastrointestinal flora and other ecological factors), and the nature of the dietary intake. Insofar as possible, the choice of this particular reference population seems to control for some of these variables in respect to the village population. However, the results cannot be considered as valid for different populations who live in different geographical, dietary and cultural settings. At this time it cannot be assumed that the results are applicable to the urban or highland populations of Guatemala.

Another consideration relates to biological and statistical variability. The nutrient loss was computed from a difference between averages. The variability around these averages was handled through estimating the standard error of the difference. Still another problem includes the consistent drop in absorption noted between the first and second sequential balance periods. There was also individual variability from balance to balance. Thus, no prediction can be made for an individual based on the results of a prior balance.

Table III

Epidemiological Malabsorption and Food Wastage in the Study Villages

Population	Calories	Fat	Nitrogen
Reference Population			
% absorption	92	85.8	85.3
Florida Aceituno[1]			
% absorption[2]	89.2	83.6	77.2
% malabsorption	2.8	2.2	6.1
Malabsorption/person/day[3]	78.4	0.6 grams	1.1 grams
Cost/person/year[4]	$ 4.76	$ 0.11	$ 0.36
Guanagazapa[1]			
% absorption[2]	92.3	90.2	84.2
% malabsorption	None	None	1.1
Malabsorption/person/day[3]	None	None	0.2 grams
Cost/person/year[4]	None	None	$ 0.07
Combined Villages[1]			
% absorption[2]	90.8	86.9	80.7
% malabsorption	1.2	None	4.6
Malabsorption/person/day[3]	33.6	None	0.8
Cost/person/year[4]	$ 2.04	None	$ 0.26

1. Data is for the last detailed absorption study (1976) and includes all subjects (both those who participated in all four annual tests and those who missed one or more tests but were studied in 1976) and is age adjusted to 26 years 10 months (see Volume II, Results of Field Studies, page 158).

2. Mean for all subjects (standard error and significance are shown in Volume II, Results of Field Studies, pages 161-163).

3. Malabsorption/person/day was computed on the basis of the following dietary intake:

Kcal/day	2800
Grams/fat/day	29.27
Grams/nitrogen/day	17.15

4. Cost/person/year was computed on the basis of diet and market surveys done in each village during 1974 and does not take into account any inflation in food prices between 1974 and 1976:

2800 Kcal	$0.466
29.27 grams fat	0.015
17.15 grams nitrogen	0.016

Table IV.

Comparison of Malabsorption Costs Between 1973-74 and 1976 Per Person and By Village

Village	Unit	Cost in U.S. Dollars Calories	Fat	Nitrogen	Total
Florida Aceituno	Person/year 1973-1974[1]	4.42	0.36	0.45	5.23
	Person/year 1976	4.76	0.11	0.36	5.23
	Total population/year 1973-74[2]	3166.93	257.94	343.82	3768.69
	Total population/year 1976	3707.36	89.46	359.42	4156.24
Guanagazapa	Person/year 1973-74[1]	2.04	0.09	0.28	2.41
	Person/year 1976	None	None	0.07	0.07
	Total population/year 1973-74[2]	1565.70	276.30	347.81	2189.81
	Total population/year	None	None	305.64	305.64
Combined Villages	Person/year 1973-74[1]	3.23	0.21	0.37	3.81
	Person/year 1976	2.04	0.11	0.26	2.41
	Total population/year 1973-74[2]	4737.70	316.02	553.46	5607.18
	Total population/year 1976	3351.72	None	427.18	3778.90
Decrease in malabsorption costs between 1973 and 1976 (both villages).		1385.98	316.02	126.28	1828.28

1. Costs were computed on mean percent malabsorption for the years 1973-74 combined (see Table IX, page 170, 176 annual report of the project).

2. Adult females were assumed to have the same losses as adult males (≥ 15 years) while children (< 15 years) were assumed to have one-half of the loss of an adult male. The population data used in these computations were:

	Florida		Guanagazapa		Combined	
	1974	1976	1974	1976	1974	1976
< 15 years	389	424	487	498	876	922
> 15 years	522	582	524	600	1046	1182

VII. Policy Implications

The policy implications of the findings on the economic costs of food wastage indicate that these losses are present, but are small. Food losses in production, storage and transportation are thought to be much more significant in terms of food wasted. A search of the literature gave estimates of ten to fifty percent of all food as being lost along the production-distribution-marketing-consumption chain before the food reaches the table. These estimates are without rigorous substantiation and are used here merely as a policy bench-mark for comparison with the extent of wastage due to intestinal malabsorption. However, in making this internal to external food wastage comparison, one misses the essential element in the food wastage calculation. Food wastage from intestinal inefficiency is the consequence of a chain of human stresses ranging from diarrheal disease to tropical enteropathy and is linked to poor sanitation and level-of-living conditions. The calculation has to be based on the complex of stresses rather than limited to the cost of food.

An original question for the study was whether policy-makers should take on research projects in their countries to identify the costs of food wastage. Obviously, the calculations for the Guatemalan villages cannot form the basis for policy in other countries and geographical areas. Yet, the results of this study indicate, a) much must still be learned about the water supply/diarrheal disease/malabsorption linkage and b) losses from malabsorptive food wastage in a population does not lead to the loss of large amounts of food. However, scientific research in malabsorption, diarrheal morbidity and health status should be

done so that future policy research will be based on better methods, information and knowledge. At present, policy research in this area is limited by difficulties in quantifying the economic variables, defining "normality" for food wastage in a population and explaning the biological variability in individuals in repsect to malabsorption. Further constraints relate to the measurement of morbidity and sanitation. This study did not reach any definitive answers with respect to quantification of health benefits from environmental improvements. This finding matches the current situation in respect to the quantification of health benefits. Researchers in the field are currently reviewing the strategies and potential for research in the measurement of health benefits from water supply. For instance, the I.B.R.D. report notes, ".....,it is extremely difficult to identify and measure exactly the health effects of improved water supply, and there is a limit to the precision attainable".

The contributions of the UNC/INCAP study have not been in the exact quantification of health benefits. The accomplishments have been in the developing and testing of methods, the development of indicators, and in findings which provide an information base for further studies in policy and scientific research.

<u>These findings include</u>:

1.) <u>Water Consumption and Utilization</u>

a.) Water containers for storage were found to be recontaminated after they were filled with potable water. The provision of a piped water supply led to direct use of the water from the tap and an improvement in the water quality at the point of consumption and use.

b.) A careful record of daily use showed the quantity at which

water usage levelled off despite the availability of additional water at no increased cost. This figure may represent a benchmark for calculating needs in future studies of water supply demand.

c.) The field study, over the limited period of four years, did not demonstrate that a safe and available water supply leads to a decrease in diarrheal morbidity. This negative finding may be among the most significant findings of the study. The constraints of time and limits of the method available have been discussed, and recommendations for future studies have been proposed. However, the results of the study confirm what experts have surmised. When the study started, there was still confidence that the direct relationship between water supply and diarrheal disease could be demonstrated in the field. Epidemiologists now have reservations about the usefulness of these field studies because of the difficulties in isolating the numerous variables involved. This study has helped in delineating the operational details of these difficulties and has led to new concepts, strategies, experimental designs and methods which may be used in future studies. The investigators in this study agree with the I.B.R.D. report that limited studies to establish methods, information and data bases are needed. Also needed are research studies to increase the current state of knowledge of disease etiology and health benefits quantification. These are required before any further large-scale policy research is undertaken.

2.) This study did emphasize the importance of investigating for

educational, behavioral and cultural variables. The health education component, in particular, offers a guide to methods for family and community involvement in water use and sanitation behavior. Also, methods for measuring knowledge, attitudes and behavior were explored.

The health education component is documented in the methodology report and the protocols and forms used are described. The UNC/INCAP study incorporated health education as an integral part of the environmental improvement input and approached this component with rigor in regard to measurement and data collection.

3.) The details of the data management system are presented elsewhere in this report. The experimental design and statistical requirements of these complex studies require levels of expertise and technical sophistication that are not available in most of the LDC's. This requirement severely limits the possibilities for such studies. It must be admitted that even UNC-CH and INCAP did not fully appreciate the data management needs at the outset of the study. However, the development of the data management system for the study has been fully documented and the record of its application in the study will serve as a useful resource for other studies. A comparable study should not be undertaken without careful planning, competent personnel and complete facilities for data management. These factors constitute a major constraint for studies in the LDC's where there are few such personnel and facilities available.

4.) The census, just one element in the data management system, illustrates some of the problems which must be addressed in such a study. The census method used required that the interviewers survey each house in the village every month. This required an extensive utilization of time, personnel, and resources. The

outcome was especially interesting in view of the unexpected mobility in and out of the villages. This mobility has implications for the length and continuity of the impact of the environmental improvements. However, there are questions of balancing the objective of complete and indepth data collection against the expense in money and scarce personnel resources required for gathering such complete data. The injunction that "the methods of data collection should be as simple as possible, while retaining as high a degree of reliability as possible" is correct, but not particularly useful in an operational context.

5.) The morbidity survey also illustrates the complexity of the data management system. Morbidity data showed the same distribution of diarrheal morbidity as seen in a number of other studies, whether these studies used similar recall procedures or other methods for measuring of morbidity. Yet, there is a question as to what the diarrheal disease data means in terms of input-output relationships. There seems to be little agreement on the optimum epidemiological method for diarrheal disease surveillance. The inherent difficulty may be that diarrheal disease is a symptom complex rather than a disease. Mansourian, et al., note, "It seems certain that there are multiple causes and that the precipitating event may often be of less significance that the background and the reaction of the individual to it". Economists and engineers involved in water studies rarely appreciate the uncertain state of the art in carrying out diarrheal disease surveys. Though benefit studies require that the health effects be listed as discrete categories, the actual state may be more correctly expressed as dynamic. Mansourian, et al., have tried to redefine the diarrheal incident in terms of the diarrheal signal for subsequent pattern analysis. Investigators in this study pointed to the importance of onset, frequency

and persistence of the bowel movement. In any event, the study has indicated the need to measure diarrheal incidents in terms of processes rather than as a categorical disease.

6.) Other findings from the study relate to new data and concepts for malabsorption and food wastage. The study did establish the presence in the Guatemalan rural lowlands population of a low level of "population malabsorption" which has been discussed in this report. This finding does not translate into significant economic costs from food wastage (Table III and IV). However, a method for determining a reference point for a population and a level of food wastage in a population has been developed through this study. In addition, a clearer understanding of low level population malabsorption has been achieved in the process of developing the measurement method. Some examples of the new concepts and findings include:

The digestibility studies on the biological value of a mixed corn-bean rural Guatemala diet has showed the actual utilization of a diet by a given population. In these studies, three objectives were realized, including:

a.) Information on the corn-bean diet regularly consumed in the lowlands has been fragmentary in respect to its digestibility and biological value. The digestibility studies established the optimal digestibility of this diet in a young healthy population.

b.) Values were determined for obligatory nitrogen loss in young healthy population while they were receiving an essentially nitrogen-free diet.

c.) The concept and operational definition for a "reference

population" was achieved. This approach allowed the determination of "subtle" elevations in food wastage which would have been missed if the standard North American clinical criteria for malabsorption were used. These studies have enlarged the definition of malabsorption and have substituted a concept of relative malabsorption in a population for absolute malabsorption in the clinical setting. The latter approach is not relevant to the sub-clinical situations seen in the populations of the hot, poor countries.

Additional findings on malabsorption include the recording of the significant variabilities in the same person from day to day and over longer periods. In fact, this finding complicated the interpretation of results from the longitudinal population samples and points to the need for alternatives to the present complicated balance tests. There is a need for an easier test for malabsorption, primarily to permit increased frequency of testing, so that the patterns of variability can be studied.

Sampling

It is clear that this study and similar studies on health benefits depend on the ability to make a large number of measurements of diverse variables. In retrospect, the study design and sampling plan called for too many measurements for too diverse a matrix of variables. Future studies should avoid these problems through a strict requirement for a pilot study. The pilot study may accomplish two ends:

a.) Delineate clearly the sampling schedule and guide the choice of number of variables for consideration. The frequency and scheduling of sampling becomes apparent only after observation of an operating system.

b.) Permits an evaluation period at the end of the pilot study. This evaluation period can be used to determine whether to proceed with the study or terminate. The prospects for project-impact studies are not optimistic given the current state of knowledge. The expenses may be considerable. The pilot study may be designed to provide some methodological or substantive finding while accomplishing the major purpose of evaluation to contribute to a decision for continuation or termination.

No study should be embarked on without the availability of skilled investigators and competent data management resources. The LDC's usually do not have adequate resources for data management and this situation is most deficient at the middle and lower levels of programmers and data handlers. Studies on quantitation of benefits will require the training of expert data managers with particular skills in the management of research data.