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THE CHILDHOOD HEALTH EFFECTS OF AN IMPROVED WATER SUPPLY SYSTEM ON A REMOTE PANAMANIAN ISLAND

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Abstract. The incidence of diarrhea, respiratory disease, and skin infections was prospectively determined after the introduction of a system which distributed unlimited quantities of high quality fresh water to each of the 150 housing units on Tupile, an island devoid of fresh water located off Panama's Caribbean coast and inhabited by 1,500 Cuna Indians. Tupile residents used 7.1 liters of water/person/day compared to the 2.3 usage rate of inhabitants on Achutupo, the control island. Despite ready availability of water in each household, Tupile residents continued to store water in contaminated vessels prior to use. Forty percent of stored water samples tested on Tupile and 45% on Achutupo were contaminated with *E. coli* organisms. There were 4.7 episodes/child year (E/Y) of acute diarrhea on Tupile compared with the 3.5 rate on Achutupo. The rotavirus infection rate on Tupile was 0.8 E/Y compared with 0.2 E/Y on Achutupo. Infection rates for Norwalk virus, respiratory syncytial virus and Coxsackie B 1–6 viruses were similar on both islands. Respiratory disease rates were high on both islands (2.2 E/Y on Tupile, 2.7 E/Y on Achutupo). Achutupo had much higher rates of impetigo and scabies (0.6 E/Y and 2.5 E/Y, respectively) than Tupile (0.2 E/Y and 1.4 E/Y).

Provision of the water distribution system had a beneficial effect on the incidence of water-washed diseases (impetigo and scabies), but at best had no effect on diarrheal disease.

Poor quality drinking water may increase the risk of acquiring various water-borne diseases such as cholera, while access to low quantities of water may increase the risk of acquiring the so called "water-washed" diseases (e.g., skin and eye infections) by facilitating person-to-person transmission of certain agents.[1] In this prospective investigation of the health effects associated with the installation of a centralized water distribution system which delivered high quality and quantity water to the inhabitants of a remote island located 1 mile off Panama's Caribbean coast, we report the probable reasons why the new system did not decrease the incidence of diarrhea but markedly decreased the incidence of scabies and impetigo when compared to disease rates on an adjacent control island where traditional water collection methods continued to be used.

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MATERIALS AND METHODS

Subjects

The Cuna Indians are 1 of 3 Amerind groups in the Republic of Panama. They inhabit a chain of isolated, sparsely vegetated coral islands, the San Blas Archipelago. The islands of Tupile and Achutupo were selected because they were highly traditional, had stable populations, and were quite remote. We felt that these features might make our findings more applicable to similar remote rural villages in the developing world. Tupile, located 1 mile off shore, measures 1.0 km by 0.5 km and has approximately 1,500 inhabitants, all Cuna Indians, living in approximately 150 housing units made entirely out of local materials.

Achutupo, 6 miles from Tupile, is of similar size and demographic make-up. Both islands were devoid of fresh water sources. On both islands defecation is carried out in "privies" located on small platforms above the ocean; the average tide is 2 feet.

Eight months prior to the present investigation Tupile had installed a centralized water distribution system which diverted water from a mainland stream and provided high quality water to each of the island's 150 dwellings. Each house had its own spigot, and unlimited amounts of water were available 24 hr a day from each spigot. Throughout the 7-month study period the new water system remained functional. On Achutupo, the control island, women daily traveled up to 1 mile across open ocean to a stream on the largely uninhabited mainland to collect fresh water in 1 liter-sized gourds.

In August 1979, a door-to-door census was carried out on both islands. This census documented that on Achutupo there were 201 children aged less than 5 years and 192 children of the same age on Tupile. We conservatively estimated that 30% of the children on Achutupo would develop diarrhea, respiratory or skin infections during the study period. Therefore, a 50% random sample of the 393 children aged less than 5 years living on both islands was selected for inclusion in the study. These numbers were selected so as to provide the study with adequate power (80%) for a one-tailed test at the 5% level to detect a 33% decrease in the incidence of diarrhea, respiratory or skin infections in Tupile children. Of the 192 children originally enrolled and from whom an initial venipuncture blood sample had been obtained, a second blood sample could not be obtained from 14 children (6 from Tupile and 8 from Achutupo); these children were considered study drop outs. Eight study drop outs died from complications of diarrhea (5 Achutupo children, 3 Tupile children) while insufficient quantities of sera from the March venipuncture were obtained from the other 6 children. The present report includes only the 178 children who were successfully followed and from whom the 2 sera were collected.[2]

Between August and the following March, specially trained Cuna Indian epidemiology field technicians conducted door-to-door surveillance 6 days a week on each cohort child for diarrhea, respiratory and skin infections. Stool samples were collected from patients with diarrhea. The technicians' daily observations were recorded on a standard form. In March 1980, a second serum sample was obtained from all consenting members of the original cohort. We defined infection to a particular pathogen by a four-fold or greater rise in serum antibody titer to that agent between September 1979 and March 1980. Diarrhea was the passage of more than 3 loose stools/24 hr. Patients passing more than 3 loose stools/24 hr, any one of which was positive for rotavirus (RV) antigen, were defined as having an episode of RV diarrhea. Respiratory disease consisted of a productive cough and an oral temperature $\geq 38°C$. Impetigo was any purulent skin lesion developing independently of an open wound. Scabies was the onset of a scabetic-like skin rash. Each field worker was provided with a pictorial book of representative impetigious and scabetic skin lesions to assist him/her in diagnosis. An episode of diarrhea was considered to be resolved on the first day when fewer than 3 liquid stools were passed. However, if a child had 3 or more liquid stools on any day within 3 days after an episode of diarrhea, that day and the intervening days were included in the same episode. An episode of respiratory illness was considered to have terminated when the child both became afebrile and stopped the productive cough.

Laboratory

Stool samples from patients with diarrhea were collected on the first day of symptoms and stored at $-10°C$ on each island until monthly transport to our central laboratory in Panama where they were maintained at $-20°C$ prior to testing. Standard ELISA techniques were used to detect rotavirus antigen.[3] For logistical reasons bacterial enteric pathogens were not sought in the stool samples.

All serum samples were collected using aseptic technique, centrifuged within 6 hr of collection, kept at 4°C for no more than 48 hr before they were entered into the Gorgas Memorial Laboratory Serum Bank where they were stored at $-20°C$ prior to frozen shipment to Bethesda.

Rotavirus IgG antibodies were measured using standard complement fixing techniques.[4] The blocking radioimmunoassay for antibody to Norwalk virus was done.[5] Antibodies against respiratory syncytial virus (RSV) were measured by indirect ELISA.[6] Neutralizing antibodies to Coxsackie virus types B 1–6 were carried out in Vero cells using a plaque reduction technique.[7]

TABLE 1

Rates of illness and infection with diarrhea, respiratory and skin pathogens in San Blas Island children

	No. of episodes (episodes/child-year)							
	Enteric				Respiratory		Skin	
Island	Diarrhea from all causes*	RV related diarrhea	RV infection	NW infection	Respiratory disease	RSV infection	Impetigo	Scabies
Tupile	270 (4.7)†	37 (0.6)	47 (0.8)	37 (0.6)	125 (2.2)	16 (0.3)	14 (0.2)	83 (1.4)
Achutupo	174 (3.5)‡	9 (0.2)‡	8 (0.2)‡	21 (0.4)	138 (2.7)	18 (0.4)	30 (0.6)‡	126 (2.5)‡

* See text for definitions.
† (Incidence).
‡ $P < 0.05$.

Ten sentinel households (7% sample) from each island were randomly selected for periodic monitoring of water quality and quantity during the investigation. During 1 day every other month the amount of water used in each household and its fecal coliform content were measured. On Tupile the fecal coliform content of tap water and of water stored in gourds (the traditional water-storage containers still being used at the time of this investigation) was determined in each sentinel household. On Achutupo only the fecal coliform content of water stored in gourds was obtained. Stored water from gourds was sampled via a sterile pipette introduced into each container. Fifty ml of water was withdrawn from a sentinel household's storage container on both Achutupo and Tupile and placed in 10-cc aliquots in Coli-counter™ chambers (Milipore Filter Corp., Bedford, Massachusetts). Fifty-cc samples of water on Tupile from the spigots in the sentinel households were obtained after alcohol flaming of the outlet followed by letting the water run for 1 min before sampling. These samples were also placed in 10-cc aliquots in Coli-counters™. All water samples were incubated at 43°C for 24 hr in a water-jacketed field incubator designed for isolating fecal coliforms.

The Statistical Program for the Social Sciences (SPSS) was used for data analysis. Chi square tests were used to test statistical significance.

RESULTS

Tupile's pattern of water utilization and disease transmission contrasted significantly with Achutupo's. Tupile residents used approximately 7.1 l (range 1.5–13.6 l, SD ± 0.5) of water per person per day compared with the approximately 2.3 l (range 700 ml–4.9 l, SD ± 0.3) per person per day used on Achutupo. Tupile children had a significantly higher incidence of diarrhea than Achutupo children (Table 1). Rotavirus-related diarrhea and rotavirus infection were more common on Tupile than Achutupo, while the incidence of Norwalk virus infection was similar on both islands (Table 1). The incidence of respiratory diseases and of RSV infection was similar on both islands. Tupile children had a much lower incidence of impetigo and scabies compared to Achutupo children.

Water sampled on numerous occasions from Tupile's mainland reservoir, as it emanated from the taps in sentinel households on Tupile and from the mainland stream where Achutupo residents obtained their water, always contained less than 10 coliforms/100 cc. However, Tupile residents did not use water directly from their taps; they obtained water each morning from their standpipes and stored it in their traditional water-storage vessels prior to use. On Tupile 16 of 40 (40%) water samples collected directly from these vessels contained fecal coliform (mean number in positive samples of 76.1 organisms/100 cc water; range 30–140 organisms/100 cc water). Forty-five percent of 40 water samples collected on Achutupo from traditional water storage vessels contained fecal coliforms (mean number in positive samples of 142 organisms/100 cc water; range 53–203 organisms/100 cc water).

DISCUSSION

This study has several limitations which should be noted. First, a comparison of disease/infection rates on Tupile with those on Achutupo may not be completely valid. Our assumption that the only difference between the two islands was Tupile's new water system may not be accurate. While disease rates on both islands gave little indication that an epidemic might have occurred during the study, we cannot rule out the possibility that some disease clustering did occur which was completely independent of Tupile's having a water supply system and which in turn might

have misleadingly swelled the disease/infection incidence rates on that island. A second limitation of our study involves the water quality and consumption data. Larger sampling frames would have made these data more convincing. Third, subtle but important differences in disease criteria and surveillance techniques among the epidemiology technicians on each island may have occurred.

These limitations are at least partially compensated for by other features of the study. Diarrhea morbidity information was obtained 6 days a week from the responsible guardian of each cohort child. It is unlikely that the results of the study were biased by inaccurate recall. A specific etiologic agent of diarrheal disease/infection was sought in the present study. Many previous studies seeking to demonstrate an association between water quantity and quality and increased rates of diarrheal illness/infection have not sought to define the etiology of the illness.

Increased water availability on Tupile probably led to improved personal hygiene and decreased the number of skin infections. At best the new water system made no impact on diarrhea incidence due to the multiplicity of transmission modes other than water-borne of the many agents now known to produce acute diarrheal illness. The increased volumes of water actually used on Tupile were nearly as contaminated as the small volumes used on Achutupo. Following installation of the water system Tupile residents had not been made aware of the possibility that tap water stored in open containers could easily become contaminated either by the containers themselves or by the introduction of objects contaminated with enteropathogens (i.e., unwashed children's hands) directly into them. Increased use of the contaminated water may even have facilitated the transmission of enteric agents known to be transmitted by water (e.g., rotavirus). Currently available technology prevented us from detecting RV or NW particles in the contaminated drinking water.

Introduction of the water system may not have accounted entirely for the increase in RV infection/illness rate on Tupile. An increase in the rate of person-to-person transmission of enteric viruses may have occurred on Tupile. This explanation seems unlikely. The number of Coxsackie virus B 1–6 seroconversions in each individual, useful as an index of person-to-person transmission, was similar on each island (R. W. Ryder, personal communication). The incidence of RSV and NW infections also spread by close personal contact was similar on both islands. Living conditions and the degree of crowding on both islands appeared to be similar.

Improper use of the water system led to only limited health benefits following installation of this system.

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