Reduction of enteric infectious disease in rural China by providing deep-well tap water

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Enteric infectious disease (EID), defined here as bacillary dysentery, viral hepatitis A, El Tor cholera, or acute watery diarrhoea, is an important public health problem in most developing countries. This study assessed the impact on EID of providing deep-well tap water (DWTW) through household taps in rural China. For this purpose, we compared the incidence of EID in six study villages (population, 10290) in Qidong County that had DWTW with that in six control villages (population 9397) that had only surface water. Both the bacterial counts and chemical properties of the DWTW met established hygiene standards for drinking water. The incidence of EID in the study region was 38.6% lower than in the control region; however, the introduction of DWTW supplies did not significantly affect the incidence of bacillary dysentery. These results indicate that the construction and use of DWTW systems with household taps is associated with decreased incidences of El Tor cholera, viral hepatitis A, and acute watery diarrhoea.

Since high construction costs have led many authorities to question the value of DWTW, we carried out a cost–benefit analysis of the programme. The cost of constructing a DWTW system averaged US$ 36000 at 1983 prices, or US$ 10.50 per capita. The combined capital and operating costs of a DWTW system were US$ 1.46 per capita per annum over its 20-year estimated life. The benefits derived from reductions in cost of illness and savings in time to fetch water were 2.2 times the costs at present values Capital outlays were recouped in a 3.6-year payback period and the provision of DWTW proved highly beneficial in both economic and social terms.

Part 1. Evaluation of effectiveness

Considerable success has been made in improving health care in China and the life expectancy at birth in the country is now 69 years (*18*). Environmental improvements, combined with preventive medical measures, have greatly reduced the incidence of communicable diseases. Nevertheless, enteric infectious disease (EID), defined here as bacillary dysentery, viral hepatitis A, El Tor cholera, or acute watery diarrhoea, remains an important public health problem, especially in rural areas. The major infectious agents of diarrhoea are transmitted by the faecal–oral route, often through contaminated water. Several studies (*11, 17, 20, 21, 23, 24*) have reported that water plays an important role in the transmission of EID in rural China, and some counties in the country have begun to supply deep-well tap water (DWTW) to prevent such disease. The primary purpose of this study was to evaluate the impact of DWTW supplies on the incidence of EID; the results obtained are described below.

Materials and methods

Study and control regions

The study was carried out in 1983 in Qidong County, which has a population of about 1 million. Six villages (population 10290), where residents had been drinking and using DWTW for 2-3 years, were randomly chosen as the study region. The control region consisted of six other villages (population

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9397) that were chosen at random from among the neighbouring villages where residents used surface water (rivers, ditches, etc.). Microbiological and chemical determinations were carried out in 1983 on 24 specimens each of surface water and DWTW.

Characteristics of the control and study regions

The major difference between the control and study regions at the time of the investigation was the source of drinking water. Inhabitants of both regions had the same kind of natural environment, living conditions, eating habits, and socioeconomic status. As shown in Table 1, the study and control populations had similar age and sex distributions, education levels, and annual per capita expenditures in the cooperative health system. In 1980, before DWTW was available in the study region, the incidence of EID was similar in the study and control regions. The water is drawn from wells 226–312 metres' deep by hermetically sealed water pumps and piped directly to individual houses or yards. Because the system is sealed, no filtration or chlorination procedures are used. In 1983, 75% of households had tap water available inside the house, while the remainder had the tap in the yard. One tap provided water for 4.3 people on average. Each DWTW system had a permanent staff of one or two to maintain and operate the supply.

Table 1: **Selected demographic data for the study and control regions**

	Study region	Control region
Total population surveyed	10 290	9397
% males	47.37	48.09
% in age group:		
0–4 years	6.06	5.33
5–14 years	17.80	17.92
15–49 years	57.92	57.94
≥50 years	18.21	18.81
% who attended:		
College or university	0.02	0.04
Middle school	33.27	33.26
Primary school	43.97	43.20
Annual expenditure in the cooperative health system per person (yuan)	5.00 (US$ 1.67)	4.90 (US$ 1.63)
Incidence of EID (1980)[a]	280	210

[a] Per 1000 population per annum. EID = enteric infectious disease.

Diagnosis of EID

A rural doctor who was resident in each of the twelve study and control villages recorded in detail all episodes of EID between 1 June and 31 October 1983. The rural doctors saw residents who came to them when they were ill and, in addition, visited the households frequently to ask whether anyone was ill. The doctors used uniform diagnostic standards and case-finding methods. The following definitions of EID were used: diarrhoea—≥three liquid stools in 24 hours; dysentery—diarrhoea with blood or mucus and tenesmus, or diarrhoea that was culture-positive for Shigella species; viral hepatitis A—serum glutamic-pyruvic transaminase (or alanine aminotransferase) levels >80 U with clinical symptoms of fever, malaise, anorexia, nausea, or abdominal discomfort, followed within a few days by jaundice; cholera—diarrhoea with a positive culture for Vibrio cholerae serogroup O1. If required, for diagnosis of dysentery or hepatitis, patients were referred to the hospital for laboratory analysis of blood and faecal specimens. V. cholerae was identified by the Health and Anti-epidemic Centre, Qidong County. The impact of improved water supply was determined from the incidence of EID, calculated as the number of persons who contract such disease divided by the 1982 census population.

Results

Comparison of the incidence of EID after the intervention

During the 5 months of the investigation, the overall incidence of EID was 187.2 per 1000 population in the study region and 304.9 in the control region (Table 2). The incidence in the study region was 38.6% below that in the control region, a difference that is highly significant ($P < 0.001$). The incidence of bacillary dysentery was similar in both regions. No deaths from EID in either region occurred during the observation period.

Microbiological and chemical properties of the water supply

The average total bacterial count of the surface water samples from control villages was 3551 per ml, and the average coliform count was 772 per litre. In contrast, in DWTW samples from the study villages the average total bacterial count was 5.4 per ml and the average coliform count was 2.3 per litre. Chemical oxygen demand was 22.1 mg per litre for surface water and 11.0 mg per litre for DWTW samples. Bacterial counts and chemical properties in DWTW met the established hygienic standards for drinking water in China (13) and also the WHO recommended drinking water standards (10).[b]

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[b] Minimum evaluation procedure for water supply and sanitation projects. Unpublished document (WHO/CDD/OPR/83.1).

Table 2: Incidence of enteric infectious disease (EID) in the study and control regions, 1 June–31 October 1983

| | EID | | | | |
	Viral hepatitis A	Cholera	AWD[a]	Dysentery	Total
Study region:					
No. of cases	26	1	1816	83	1926
Incidence (per 1000)	2.5	0.1	176.5	8.1	187.2
Control region:					
No. of cases	88	8	2685	84	2865
Incidence (per 1000)	9.4	0.9	285.7	8.9	304.9
% reduction in study region	73.0	88.2	38.2	—	38.6
Statistical significance[b]	<0.001	0.02	<0.001	>0.05	<0.001

[a] AWD = acute watery diarrhoea.
[b] Results for cholera are based on Fisher's exact test; others based on χ^2 test.

Quantity and reliability of the DWTW supply

The DWTW supply facilities · functioned continuously throughout 1983, and except during power cuts, the quantity of water supplied was sufficient to meet the demands of users. In the summer and early autumn, however, when farm work uses large amounts of electricity, Qidong County had frequent power cuts that interrupted the water supplies. Power was typically switched off for a few hours in late morning and mid-afternoon, and residents then had no alternative but to drink and use polluted surface water. Because each DWTW system had a separate power supply, the lengths of the power cuts and of water disruption varied among the study villages and those with longer cuts had significantly higher ($P < 0.001$) incidences of acute watery diarrhoea (Table 3). A regression analysis of these incidences on the percentage of time that power was cut indicated that, if the power cuts could be eliminated, the 5-month incidence of diarrhoea in the summer and autumn would drop from 176 per 1000 population to 17 per 1000, a 90% decline.

Table 3: **Relationship between the incidence of acute watery diarrhoea (AWD) and the number of hours of power cuts in villages with deep-well tap water, 1 June–31 October 1983**

Villages	No. of hours	Population	No. of cases of AWD per 1000
Lubei, Ludong	228 (6.2)[a]	3362	114
Xiangyang, Jinhai	459 (12.5)	4014	174
Yinyang 10, 11[b]	515 (14.0)	2914	247
Average	401 (10.9)	3430	178

[a] Figures in parentheses are the percentage of 3672 potential hours (153 days × 24 hours).
[b] Variation from expected: $\chi^2 = 155$, $n = 2$, $P < 0.001$.

Discussion

As noted by Feachem (6), improvements to water supply and sanitation facilities are the most effective interventions for reducing the incidence of diarrhoeal diseases. The degree of impact often depends on the type of water supply. Four factors probably contributed to the effectiveness of DWTW in preventing EID in the present study. First, the improvement of water quality reduced the load of waterborne pathogens. Second, the increased access to water, i.e., a piped supply in the home, reduced the use of polluted sources and the opportunity for contaminating portable water. Third, when water is available in the house, it is more likely to be used for general sanitation and personal hygiene. Finally, the population liked the appearance and taste of the water, so that there was no disincentive to consuming it.

The results of the study indicate that drinking DWTW was associated with the reduction in incidence of viral hepatitis A, cholera, and acute watery diarrhoea; however, provision of such water did not seem to influence the incidence of bacillary dysentery. Esrey et al. (3) have indicated that in poor communities a limited improvement in water supply and sanitation facilities can have a greater impact on diarrhoea caused by pathogens that have a high infective dose than on diarrhoea caused by pathogens that have a low infective dose, e.g., *Shigella* spp.

As noted above, the availability of DWTW apparently reduced the incidence of EID by 38.6%. There are several reasons why the reduction was not greater. First, during the power cuts, the inhabitants in the study villages often used polluted surface water. Second, intestinal pathogens are not only spread by water (the role of water in the transmission of campylobacter and rotavirus has not been well defined). In the study only the impact of drinking relatively safe deep-well water was measured; public health measures such as personal and domes-

tic hygiene and the management of excreta were not investigated in connection with the introduction of DWTW. Third, the residents of Qidong County have traditionally eaten raw seafood (such as snails, shrimps, crabs, and clams) that is processed with salt and vinegar. Any of these foodstuffs could also transmit EID. We assume that the incidence of diarrhoeal illness and EID will be further reduced when the problems mentioned above are solved.

Improving water supplies is not only a means of preventing enteric infectious diseases, but also a way of improving other aspects of health. The entire population in the study region is now reaping the health benefits of a better water supply and this will inevitably increase their social well-being.

Part 2. Cost–benefit analysis

As shown in part 1 of this article, provision of DWTW systems is an effective and feasible way of reducing the incidence of EID. The annual mortality from liver cell cancer was also lower among persons who had used DWTW for at least 10 years (*15, 16, 22, 25*, and Zhao Ren-jie et al., unpublished results, 1986).

DWTW has been used in some villages in Qidong County since the mid-1970s. However, because the construction costs of such systems are high in relation to county health and environmental budgets, many counties and public health agencies question these investments. In view of the scarcity of resources, a precise understanding of the health benefits and costs of water supply is therefore critical.

We collected detailed information on community and individual expenditures for the construction and operation of DWTW systems and on EID in Qidong County. As far as we are aware, this is the first cost–benefit study of the provision of DWTW supplies with household taps for the prevention of EID in China.

Materials and methods

The costs and benefits of DWTW were calculated using methods described by Shepard et al. (*14*),[b] Reynolds & Gaspari (*12*), and Hsiao (*8*). For this purpose, we took the project life to be the 20-year useful life of the buildings.

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[b] **Shepard, D.S. et al.** *The cost of an oral rehydration therapy programme: a manual for managers.* Institute for Health Research, Harvard School of Public Health, 1985 (prepared for the WHO Control of Diarrhoeal Diseases Programme).

Costs of the DWTW programme

The DWTW systems were built by Qidong County's well-making team and each of the three systems constructed serves two villages, each of about 1715 people. The programme incurs both capital and recurrent (operating and maintenance) costs. Capital costs include the material and manpower used by the team to drill the well, and the cost of buildings, land, and equipment such as machines, water towers, downpipes, and water taps for each household. Recurrent costs include expenditure on upkeep (or repair), charges for electricity, and the wages of the programme administrator.

A useful life of 10 years was taken for the equipment (*4*). We assumed that investment costs were incurred at the beginning of each investment year because of the time taken for construction and installation, and that recurrent costs were incurred at the end of each project year. Costs were determined in yuan for the study year (1983) and an exchange rate of US$ 1.00 = 3.3 yuan was used. All costs were converted to present value at a real interest rate of 5%, as shown in Table 4.

Costs of illness

The costs of illness include both direct and indirect components. Direct costs involve expenditures for treatment and containment of EID; for example, expenditures on hospitalization, medical treatment and medicine, transportation of patients, laboratory examinations, isolation and disinfection, salaries and fringe benefits of health personnel, and rural doctors' salaries. Patients who were hospitalized with EID were treated by EID doctors and nurses, and so the entire salaries of these health-care providers were attributed to these cases. The salaries of rural doctors were allocated to EID depending on the proportion of visits to clinics made by patients with such diseases.[c] This proportion was calculated from the register that listed patients by diagnosis, which was maintained by all the rural clinics covered in the study. As indirect costs were included the lost wages or earnings of patients and of their relatives who looked after them during their illness; here, data were obtained from a household survey and from examination of the patients' hospital records.

Economic analysis

The affordability of the DWTW programme was assessed by the initial capital cost per capita and the annualized total cost per capita. Annualized costs were calculated by dividing the relevant present value cost by the annualizing factor (12.46), whose

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[c] See footnote *b*.

Table 4: Costs and benefits of deep-well tap water (DWTW) in the study region

	Cost (× 1000 yuan)		Incurred during years:	Present value (× 1000 yuan)
	With one DWTW system	Study region		
Capital costs:				
Drilling well	19.0	57.0	1[a]	57.0
Buildings (water tower, engine room)	21.5	64.5	1[a]	64.5
Equipment	78.2	234.6	1, 11[a]	378.6
Subtotal	118.7	356.1		500.1
Recurrent costs:				
Electricity	2.0	6.0	1–20	74.8
Administrators' wages	0.9	2.8	1–20	34.4
Equipment upkeep	0.2	0.6	1–20	7.5
Subtotal	3.1	9.4	1–20	116.7
Total costs				616.8
Benefits:				
Averted costs of EID[b]		60.6	1–20	754.9
Time saved in water collection		47.2	1–20	587.9
Total benefits		107.8	1–20	1342.8

[a] Cost incurred at beginning, rather than end, of the years indicated.
[b] EID = enteric infectious disease.

magnitude is determined by the project life and the interest rate. Economic costs were expressed on both a gross (ignoring revenues from water users) and net basis (including such revenues).

The cost–benefit analysis related the total cost of the programme to the savings in the cost of illness and in the time spent in collecting water. The gross benefit–cost ratio was defined as benefits divided by costs (2).

Results

Costs of the DWTW system

The cost at present value of constructing and operating DWTW systems for the study region over 20 years was estimated to be 616 800 yuan (Table 4). Capital costs account for 81% of this total. The initial capital cost of one DWTW system (118 700 yuan = US$ 36 000) is equivalent to 34.61 yuan (US$ 10.50) per capita, or about 24 days' wages for an average worker in China. The annualized per capita cost of the project is 4.81 yuan, which represents about 3 days' wages. Each resident of the study region (10 290 in 1983) paid water rates of 0.10 yuan per month. The resulting annual income of 12 348 yuan exceeds the recurrent costs (9400 yuan per annum), and hence the system operates at a recur-

rent surplus. This surplus is not large enough, however, to amortize the initial capital investment or to replace the equipment after 10 years.

Costs of avoided illness

Table 5 shows the average costs of EID per case according to the type of illness. All patients with EID, details of which were recorded by rural doctors, were treated. Those with El Tor cholera were isolated at home and thus incurred no hospitalization costs. Because the incidence of bacillary dysentery was similar in the study and the control regions, this disease was excluded from our analysis. The costs of supplemental nutrition and the value of gifts sent by the patient's relatives to assist towards their recuperation were as large as the expenditure on treatment and medicine, together representing 26% and 48% of the overall direct costs for cholera and hepatitis, respectively. For cholera and diarrhoea, indirect costs exceeded direct costs.

The overall incidence of EID in 5 months was 187.2 per 1000 population in the study region and 304.9 per 1000 in the control region. Epidemiological investigations suggest that, in the control region, inhabitants who used surface water that was polluted had a higher incidence of cholera, viral hepatitis A, and acute watery diarrhoea than those who

Table 5: **Average cost per case of enteric infectious disease (EID)**[a]

	Cost (yuan)					
	Viral hepatitis		Cholera		Diarrhoea	
Direct costs:						
Hospitalization	8.40	(1.8)[b]				
Treatment and medicine	150.20	(31.8)	30.00	(12.9)	1.00	(23.3)
Laboratories	6.40	(1.4)	6.50	(2.8)		
Supplemental nutrition and sending presents	167.50	(35.4)	30.00	(12.9)		
Disinfecting premises	4.24	(0.9)	3.00	(1.3)		
Salaries and fringe benefits of health personnel	7.20	(1.5)	33.51	(14.4)	0.15	(3.5)
Wages of rural doctor	0.30	(0.1)	0.30	(0.1)	0.30	(7.0)
Transportation	5.00	(1.1)	6.80	(2.9)		
Chemoprophylaxis			3.57	(1.5)		
Subtotal	349.24	(73.9)	113.68	(48.8)	1.45	(33.8)
Indirect costs:						
Lost earnings of patients and their relatives	123.54	(26.1)	119.28	(51.2)	2.84	(66.2)
Total	472.78 (100)		232.96 (100)		4.29 (100)	

[a] All cases of EID were treated.
[b] Figures in parentheses are percentages of total costs.

used DWTW supplies—the incidence of cholera, viral hepatitis A and acute watery diarrhoea in the study region being reduced by 88.2%, 73.0%, and 38.2%, respectively.

Cases of diarrhoea and hepatitis occur throughout the year in Qidong County, but are most common from June to October. An estimate of the number of cases of EID that were averted per annum among DWTW users in the study region was obtained by extrapolating from the 5-month study period using the relationship:

No. of cases averted =

$$\frac{\text{(No. expected)} - \text{(No. found)}}{\% \text{ of cases from June to October}}$$

where the expected number of cases was expressed as the incidence in the control region multiplied by the population in the study region.

We assume that the number of cases of acute watery diarrhoea and viral hepatitis A in the study period represent 65% of the annual number and that the cholera cases represent 90% of the respective annual number. A total of 1846 cases of presumed EID were averted per annum in the study population as a result of using DWTW supplies (Table 6). These cases constitute a 38.6% reduction in the overall incidence of EID since the programme began. Acute watery diarrhoea accounted for 94% of the EID cases. If the attack rate of EID remains constant in the coming years, the predicted total avoided expenditure on illness, i.e., the direct economic benefit attributable to using DWTW supplies, will be 60 578 yuan per annum.

Time saved in fetching water

The installation of a convenient village water supply system greatly reduced the time spent in carrying water, as has been reported previously in many countries (*1, 5, 7*). Without a running supply, household members would have had to make three trips each day to carry water for people and livestock from rivers or ditches situated 10–40 metres away from their houses. The time devoted to collecting this water was estimated from a small survey in the

Table 6: **Annualized costs of illnesses that were averted by using deep-well tap water in the study region**

	Viral hepatitis A	Cholera	Diarrhoea	Total
Cost of illness per case (yuan)	472.78	232.96	4.29	
No. of cases averted per annum	108.2[a]	8.6	1729.5	1846.3
Total savings (yuan)	51 154.80	2003.46	7419.56	60 577.8

[a] Estimated as $((0.936\% \times 10\,290) - 26)/65\% = 108.2$

	Diarrhoea	
2.9)	1.00	(23.3)
2.8)		
2.9)		
1.3)		
4.4)	0.15	(3.5)
0.1)	0.30	(7.0)
2.9)		
1.5)		
8.8)	1.45	(33.8)
1.2)	2.84	(66.2)
0)	4.29	(100)

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oea	Total
29	
5	1846.3
56	60 577.8

control village to average 20 minutes per household per day. There were 3165 households in the study region, and the average daily wage in Qidong County was 1.47 yuan. A working day was conservatively estimated to be 12 hours, and hence the hourly wage was at least 0.1225 yuan. Thus, in terms of time saved alone, the availability of tapped water directly in households in the study region amounted to 47172 yuan per annum (3165 households in the study region × 20/60 hour per day × 365 days per year × 0.1225 yuan per hour).

Additional benefits

Qidong County is hyperendemic for liver cell cancer (mortality rate, approximately 50 per 100000). Su De-long, who studied the possible factors and causes of the hyperendemicity rates in the region, suggested that this cancer may be associated with drinking stagnant or ditch water (15); the installation of DWTW in 1977 reduced the mortality from liver cancer in the region (Zhao Ren-jie et al., unpublished results, 1986). Estimates indicate that after 10 years of DWTW, the incidence of liver cancer in the study region might be reduced by five cases per annum. An average case of liver cell cancer costs about 5515 yuan for medical treatment and entails about 15–20 years of lost wages from premature death (Zhao Ren-jie et al., unpublished results, 1986). Potentially, DWTW systems could result in an annual saving of about 27575 yuan for costs associated with liver cancer after 10 years (or 130700 yuan at present value). Since, however, a causal link between liver cancer and drinking stagnant or ditch water has not been confirmed, these benefits were not included in the study.

Use of DWTW can also help to control other water-related conditions, such as skin and eye infections, dermatosis, gynaecological conditions, parasitic enteric diseases, as well as vector-borne diseases (5, 9). Also, a DWTW supply has many intangible benefits. For example, many of the residents who were interviewed praised the convenience and simplicity of the running water system and noted that provision of the service was one of the first improvements made by the county government to their rural area and that it will benefit future generations. In addition, industry and agriculture are already profiting from the DWTW supply. None of these benefits were, however, included in the analysis.

Cost-benefit analysis

Table 7 presents the results of a cost–benefit analysis of the DWTW project from a societal viewpoint. Overall, the net benefits were positive and were 2.2 times the costs. If the benefits of reduced liver cancer

Table 7: Results of the cost–benefit analysis of the availability of deep-well tap water in the study region

	Benefits	Costs	Net benefits
Total, present value (× 1000 yuan)	1342.8	616.8	726.0
Total, annualized (× 1000 yuan)	107.7	49.5	58.3
Per capita, annualized (yuan)	10.47	4.81	5.66
	(3.17)*	(1.46)	(1.72)

* Figures in parentheses are US$.

were causally related to DWTW, the benefit–cost ratio would rise to 2.4. The user fees paid by residents are only about a quarter of the benefits they derive from either the costs of avoided illness or in time savings, and the right to use DWTW is therefore valuable from the users' viewpoint.

Economic loss due to power cuts

As indicated in part 1 of this article, Qidong County has frequent power cuts that reduce water supplies in the summer and early autumn when farm work requires large amounts of electricity. About 90% of the cases of diarrhoea could, however, be averted if interruptions to water supply could be eliminated. Since currently the expenditure per case of diarrhoea amounts to 4.29 yuan, such interruptions cost 2348 yuan per annum in the study region.

Discussion

The Alma-Ata Declaration urged that primary health care include the provision of adequate supplies of safe water and basic sanitation (19). Stimulated by the International Drinking Water Supply and Sanitation Decade (1981–90), China is making great efforts to improve water supplies in both urban and rural areas. The experience of Qidong County that we have reported has shown that local governments and health bureaux can make a contribution by providing a DWTW supply. Such systems can improve the quality of and increase the availability of water, so that more can be used for general sanitation and personal hygiene. As we have shown, DWTW appears to reduce the incidence of cholera, viral hepatitis A, and acute watery diarrhoea.

In order to offset the power shortages in Qidong County, which frequently resulted in water supplies being cut off in summer and early autumn, it may be useful for DWTW systems to install larger water towers or back-up generators, or to switch heavy uses of power, e.g., pumping of water for irri-

gation, to off-peak times to avoid interruptions in the water supply. In Qidong County, the initial construction cost per capita of the DWTW system was 34.61 yuan (US$ 10.50), and the per capita annualized cost was 4.81 yuan (US$ 1.46). These costs are 83% below those cited by WHO, which reported initial construction costs of US$ 60 per capita (median value) and an annual cost of US$ 10 per capita for water systems in 87 developing countries (3). Sensitivity analysis of the results indicates that discount rates from 2% to 10% do not affect our conclusions significantly.

There are a variety of possible explanations for the lower costs of providing DWTW in China. First, the equipment (machines, pumps, pipes, etc.) is all manufactured internally; in contrast, in other developing countries the majority of such equipment is imported from developed countries. Second, expatriate technician assistance is not needed in China, and the local labour rates are low. Third, one or two permanent employees were assigned to maintain and operate each DWTW system, thus ensuring local expertise to repair machines and pumps, should they malfunction.

A favourable benefit–cost ratio of 2.2 for investment in DWTW systems was found. The social benefits complement the economic benefits of reduced morbidity and of time saved. The DWTW supply has proved its effectiveness and feasibility in Qidong County and is widely accepted there; by the end of 1985, 57% of the county's population used such water supplies, a considerable increase from the 27% at the end of 1983.

The experience of the inhabitants of Qidong County that we have reported here should apply to comparable rural areas elsewhere in the world, and a DWTW programme is likely to be worthwhile wherever inhabitants are currently relying on contaminated surface water. A high population density makes feasible the supply of piped water to households. Also, in countries that have enough skilled manpower and are sufficiently developed industrially to permit the construction and maintenance of a DWTW system with local resources, the cost of such systems should be relatively low. We believe that many areas of China and other countries would realize benefits as favourable as those in Qidong County.

Résumé

Réduction des entérites infectieuses en Chine rurale grâce à l'adduction d'eau provenant de puits profonds

Cette étude examine l'efficacité de l'adduction d'eau provenant de puits profonds dans la lutte contre les entérites infectieuses dans les campagnes chinoises et en propose une analyse coût-avantages. Les entérites infectieuses dont il s'agit sont le choléra el tor, la dysenterie bacillaire, l'hépatite A et la diarrhée aqueuse aiguë. Les réseaux de distribution d'eau provenant de puits profonds ont été réalisés par l'équipe de puisatiers de la région de Qidong. Des pompes hermétiques puisent l'eau entre 226 et 312 m de profondeur et l'amènent directement à l'intérieur des habitations ou dans la cour. Il n'y a ni filtration, ni chloration, étant donné que l'adduction s'effectue dans un système hermétiquement fermé.

Une étude épidémiologique a été réalisée dans 12 villages, totalisant 19 687 habitants, de la région de Qidong afin de déterminer dans quelle mesure l'établissement de réseaux distribuant l'eau provenant de puits profonds jusque dans les foyers pouvait interrompre la transmission des entérites infectieuses. L'étude épidémiologique a porté sur la période du 1er juin au 31 octobre 1983. Le canton étudié comprenait six villages de la région de Qidong choisis au hasard, totalisant 10 290 habitants et pourvus de réseaux d'adduction d'eau potable et à usage ménager depuis deux ou trois ans. Le canton témoin réunissait six villages avoisinants, totalisant 9937 habitants, dont les résidents consommaient des eaux de surface non traitées. Les habitants des deux cantons jouissaient du même environnement naturel et avaient le même genre de conditions de vie, d'habitudes alimentaires et de statut socio-économique. En 1980, époque où les habitants des deux cantons consommaient de l'eau de surface, l'incidence des entérites infectieuses était similaire.

Efficacité du programme

Les comptages bactériens et l'analyse chimique de l'eau de distribution correspondaient aux cri-

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tères hygiéniques normaux de l'eau potable. L'incidence des entérites infectieuses dans le canton étudié (187 cas par mille habitants) était de 38,6% inférieure au taux constaté dans le canton témoin (304 cas par mille habitants), soit une différence hautement significative ($P < 0,001$). Les effets de l'adduction d'eau sur l'incidence de la diarrhée n'étaient pas liés à l'âge. L'établissement de réseaux d'adduction d'eau provenant de puits profonds n'a pas eu d'effets significatifs sur l'incidence de la dysenterie bacillaire mais s'est accompagné d'une diminution de l'incidence du choléra el tor, de l'hépatite A et de la diarrhée aqueuse aiguë.

Evaluation des coûts

Coût des réseaux de distribution. Le coût en capital de la construction d'un réseau de distribution d'eau provenant de puits profonds desservant 3430 personnes a été en moyenne de US$ 36 000 (118 700 Y), soit US$ 10,50 par tête. Les dépenses renouvelables annuelles se sont élevées à 946 dollars (3120 Y) par réseau, soit 0,27 dollar par tête. Chaque ménage desservi a payé une redevance de 0,36 dollar (1,20 Y) par an. La recette annuelle apportée par les redevances des utilisateurs, soit 1247 dollars (4120 Y), dépassait les frais renouvelables. En d'autre termes, si l'on ne tient pas compte de l'amortissement, le réseau produit un excédent régulier. Trois réseaux ont été nécessaires pour desservir la totalité de l'aire étudiée (un réseau pour deux villages).

Coûts dus aux maladies. Le coût économique moyen par cas, comprenant le traitement, le transport et la perte de gain des patients et de leur famille, s'élève à 143 dollars pour l'hépatite A, 40 dollars pour le choléra et 1,30 dollar pour la diarrhée aqueuse aiguë. L'adduction d'eau potable provenant de puits profonds a permis d'éviter chaque année dans le canton étudié un total de 1846 cas présumés d'entérites infectieuses. Le coût total de la morbidité par entérites infectieuses qui a pu être ainsi être évitée dans le canton étudié atteint 18 357 dollars (60 580 Y) par année.

Economie de temps sur l'approvisionnement en eau. Le temps utilisé quotidiennement pour l'approvisionnement en eau était en moyenne, dans le canton témoin, de 20 min par ménage. Le gain de temps résultant de l'adduction directe de l'eau aux logements a donc pu être évalué à 14 300 dollars (47 170 Y) par an sur la base des salaires relevés en 1983.

D'autres enquêteurs ont constaté que l'incidence du carcinome hépato-cellulaire était

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moindre dans les cantons de la région de Qidong qui disposent de réseaux d'adduction d'eau provenant de puits profonds depuis plus de dix ans. S'il y a bien relation de causalité entre les deux faits, le canton étudié aura économisé en outre 39 610 dollars (130 700 Y) en frais de traitement sur 20 ans.

Analyse économique

Analyse coût-advantages. Tous les coûts et avantages ont été actualisés sur 20 ans au taux de 5%, 20 années représentant la durée de vie utile des constructions et du puits. La durée de vie utile du matériel étant de 10 ans, la valeur actualisée comprend le remplacement de tout le matériel au cours de la onzième année. Dans l'ensemble, les avantages économiques des réseaux d'adduction d'eau provenant de puits profonds sont égaux à 2,2 fois leur coût. Les redevances payées par les utilisateurs correspondent à un quart seulement des avantages que le système leur procure. Si l'on tient compte du cancer du foie dans l'analyse, le rapport coût-avantages s'élève à 2,4.

Pertes économiques dues aux coupures de courant. En été, et au début de l'automne, lorsque les travaux agricoles nécessitent d'importantes quantités d'électricité, la région de Qidong souffre de fréquentes coupures d'électricité qui interrompent l'alimentation en eau. Plus les coupures d'électricité se prolongent, plus l'incidence de la diarrhée aqueuse aiguë est élevée. Une analyse des données par régression linéaire montre que 90% des cas de diarrhée aqueuse aiguë pourraient être évités si l'on pouvait éviter toute interruption dans la distribution d'eau. Les différentes stratégies utilisables à cet effet comprennent l'installation et l'entretien de réservoirs de stockage de plus grande capacité, de générateurs de secours, ou la réduction pendant les périodes de pointe de la consommation d'électricité à d'autres fins. Les dépenses courantes s'élevant à US$ 1,30 par cas de diarrhée aqueuse aiguë, il serait justifié de dépenser un supplément de US$ 712 par an et par réseau d'adduction si l'on pouvait à ce prix éliminer les interruptions de distribution.

Le coût par tête d'un réseau d'adduction d'eau, qui s'élève à US$ 1,46 sur une base annualisée, est d'environ 83% inférieur au coût des réseaux évalués par l'OMS dans 87 pays en développement. Ce faible coût est probablement dû à plusieurs facteurs. La Chine a été capable de fabriquer elle-même les pompes et le matériel nécessaire; des équipes locales ont pu concevoir et installer tous les réseaux sans assistance tech-

nique extérieure; des agents locaux permanents, employés à plein temps, ont été affectés à l'entretien et à l'exploitation de chaque réseau, de sorte que l'on pouvait disposer pour les réparations d'un savoir-faire local d'un coût modique. Un programme d'adduction d'eau provenant de puits profonds est de nature à améliorer la santé partout où la population doit actuellement se contenter d'eau de surface contaminée et utiliserait exclusivement de l'eau de distribution provenant de puits profonds si elle en disposait. L'établissement de réseaux d'adduction amenant l'eau jusqu'aux logements est faisable dans les régions à population dense. Si une nation dispose d'une main-d'œuvre qualifiée suffisante et si son développement industriel permet la réalisation et l'entretien d'un réseau d'adduction provenant de puits profonds à l'aide des seules ressources locales, les coûts sont relativement bas. De nombreuses régions rurales de Chine et d'autres pays sont sans aucun doute à même de s'assurer des avantages aussi favorables que ceux dont bénéficie la région de Qidong.

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