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PEOPLE-CENTRED APPROACHES TO WATER AND ENVIRONMENTAL SANITATION

Field test of a silver-impregnated ceramic water filter

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The silver-impregnated Ceramic Water Purifier (CWP) is a low-cost household water filter that removes micro-biological contamination at the point of use. One thousand CWPs were distributed in twelve Cambodian villages to test their effectiveness under conditions of rural household use. Water quality tests (n=686) were conducted to measure filter performance. A control group comparison survey (n=201) and a baseline and follow-up survey (n=1,000) measured impacts on household health and expenses. Ninety-nine percent of CWPs produced water meeting WHO 'low risk' guidelines or better (10 or fewer E. coli per 100 ml). Households that used CWPs experienced significantly lower incidence of diarrhoea than households without CWPs. Households that had previously boiled their drinking water experienced savings in time and expenses after using the CWP. The CWP's low production cost (US$5.50) opens the possibility of reaching large numbers of the rural poor through sustainable market channels.

Introduction

Domestic point-of-use water treatment is emerging as an important tool for reducing the risk of disease caused by drinking unsafe water, especially in areas where conventional water supply systems are not practical in the short-term due to high capital costs, chemical contamination of groundwater sources, or other factors (WHO, 2003). Filtration through porous ceramic media impregnated with silver is one in a range of low-cost technology options available for producing clean drinking water at the household level. This paper presents the results of field trials conducted in Cambodia to test the effectiveness of this technology under conditions of rural household use [Note 1].

The Ceramic Water Purifiers (CWPs) used in the field trials were produced in Cambodia using local clay mixed with sawdust (26% sawdust by weight) and formed into a pot-shape using a press mould. The sawdust burns away during firing leaving a porous filter element, which is then coated on the inside and outside surfaces with 300 millilitres of 200 ppm colloidal silver solution. The ceramic filter element is set in a plastic receptacle tank with a plastic lid and a spigot (Figure 1). The filter element is manually filled with approximately 10 litres of water from a contaminated source. The water seeps through the clay at a rate of 2 to 3 litres per hour. In Cambodia, the production cost of the CWP is approximately US$5.50 [Note 2].

Previous investigations indicate that the filtering effect of the clay eliminates a large portion of water-borne pathogens but that the silver is necessary to achieve complete disinfection. Lantagne (2001) found that the CWP effectively deactivates 98-100 percent of E. coli, Cryptosporidium, and Giardia under laboratory conditions.

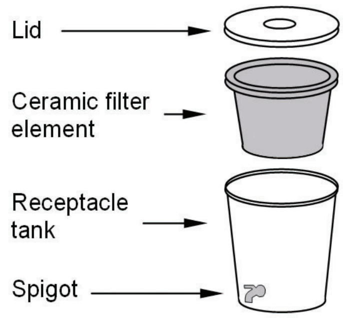

Figure 1. Parts of the Ceramic Water Purifier

The effective lifespan of the CWP is not known precisely. Limited long-term test results reported in Lantagne (2001) indicate that it may remain effective for up to seven years. In Central America, users are advised to recoat their filter elements with colloidal silver each year. In Cambodia, users are advised to replace the filter element at three years.

Implementation

From July 2002 to January 2003, CWPs were distributed to 1,000 households in twelve rural villages in Kampong Chhnang and Pursat provinces in Western Cambodia. Adult females from the selected households received training on CWP operation and maintenance and basic hygiene information regarding the causes of diarrhoeal disease, the importance of dinking clean water, and the importance of washing hands and cups. Training consisted of approximately one half hour of instruction and demonstration in groups of 20 women plus distribution of a pamphlet with text and graphics presenting

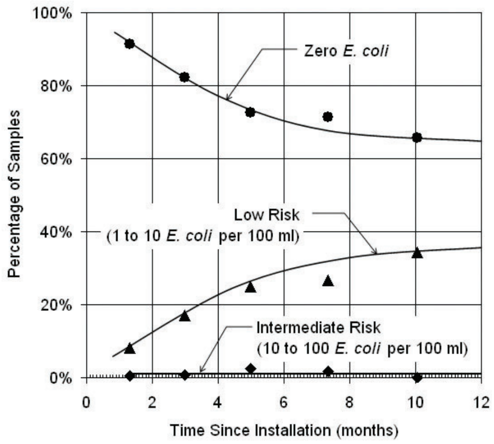

Figure 2. CWP water quality versus time installed in household

the same information. Following the CWP distribution, Field Trainers made short informal unscheduled visits to individual CWP recipients approximately once per month to reinforce training messages and monitor project impacts.

Water quality tests

Between August 2002 and June 2003, micro-biological water quality tests were conducted on 686 water samples collected from the CWPs in households chosen randomly from the entire population of recipients. Samples were collected in sterile bottles and refrigerated until tested by the Ministry of Health's National Laboratory for Drug Quality Control in Phnom Penh. The membrane filtration method was used to determine the count of thermo-tolerant coliform bacteria (faecal E. coli) per 100 millilitres.

In addition to the 686 regular samples, 75 randomly selected duplicate samples were also submitted for testing. Duplicate samples were taken from the same source at the same time as one of the other samples and were not identified as duplicates to laboratory staff. Four out of the 75 duplicates (5%) showed an inconsistency in the count of fecal E. coli. An inconsistency was defined as a variance of at least one order of magnitude between two samples from the same source. We conclude that the laboratory produced reasonably consistent and replicable water quality results.

The input water for the household water quality tests consisted of untreated water from the normal water source of the recipient household. Samples of the untreated input water were taken from 71 water points within the project villages. Sampling sites were selected to provide broad coverage of the normal water sources used by recipient households including open wells (57% of households), rivers/lakes (20%), ponds (14%), and tube wells (8%). Samples were collected in three batches between April and June 2003. Among the water sources tested, pond water was found to have the poorest water quality (70% of the samples rated as 'intermediate risk' or worse), followed by tube wells and open wells (each with 41% 'intermediate risk' or worse), and finally rivers/lakes (33% 'intermediate risk' or worse) [Note 3].

Table 1 presents the results of the household water quality tests. Ninety-nine percent of the CWPs installed in rural households produced water meeting WHO 'low risk' guidelines or better, and 1% of the CWPs produced 'intermediate risk' water. No CWPs produced 'high risk' or 'very high risk' water.

The water-quality results in Table 1 are disaggregated in three ways. First, results are broken down by the length of time that had elapsed since installing the CWP to test the hypothesis that the number of CWPs producing good quality water would decrease over time. The data indicate that the percentage of CWPs producing 'low risk or better' water remains relatively constant, varying between 98% and 100%. There was, however, a shift over time toward more 'low risk' and fewer 'zero E. coli' samples, indicating a marginal reduction in water quality for some users over time. The trend appears to stabilize after one year with approximately 64% of CWPs producing 'zero E. coli' water and approximately 34% producing 'low risk' water (Figure 2).

Second, results are broken down by water source to test the hypothesis that the quality of output water would vary with the quality of the input water. Results in Table 1 have been adjusted to account for the length of time elapsed since installation [Note 4]. The time-corrected values show relatively little variation in the proportion of 'zero E. coli' samples and 'low risk' samples except for rainwater, which had no 'low risk' samples. The variation that does exist among the other input water sources is not strongly correlated to the water quality of each source. Thus, CWPs appear to be equally effective at purifying water regardless of the input water quality, within the limits of the input sources tested.

Third, results in Table 1 are also disaggregated by the gender of the household head to test the hypothesis that the CWP effectiveness would differ in male- and female-headed households. Results indicate that the quality of the CWP water produced in female-headed households was better than in male-headed households but only marginally so.

Household impact surveys

In August 2003, after nearly one year of CWP use (11.3 months on average), a sub-set (n=101) of the total CWP-recipient population was surveyed to determine the impact on CWP households relative to a control group (n=100) that did not have CWPs. Only households that used open wells and/or ponds as their primary water source were included in the survey. These are two of the poorer quality water sources commonly used in rural Cambodia and thus provided an opportunity to assess the CWP under 'worst case' conditions. Two CWP project villages were selected based on the large number of residents using open wells and ponds as water sources. 101 respondents were selected randomly in the two villages from a list of CWP recipients who used those water sources. For each of the project villages, a nearby control

Table 1. Results of Post-Installation Water Quality Tests

Percentage of samples conforming to each WHO risk category	Entire sample	Disaggregated by elapsed time since installation: 0 to 2 months	2 to 4 months	4 to 6 months	6 to 9 months	9 to 12 months	Disaggregated by water source: Tube well	Open well	Pond	River or lake	Rain water	Disaggregated by gender: Male-headed household	Female-headed household
Conforms to WHO Guidelines (zero E. coli)	81%	91%	82%	73%	71%	66%	83%	81%	78%	80%	100%	79%	83%
Low Risk (1 to 10 /100 ml)	17%	8%	17%	25%	27%	34%	15%	18%	21%	17%	0%	19%	16%
Intermediate Risk (10 to 100 /100 ml)	1%	1%	1%	2%	2%	0%	2%	1%	1%	3%	0%	2%	1%
High Risk or Very High Risk (>1000 /100 ml)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Risk or better (0 to 10 /100 ml)	99%	99%	99%	98%	98%	100%	98%	99%	99%	97%	100%	98%	99%
Sample size *	686	219	123	168	56	32	54	386	94	107	7	394	256

* The sum of the disaggregated sample sizes is less than the total sample size because the elapsed time, water source, and household gender were not available for every CWP test.

Table 2. Selected Results from the Household Impact Survey

	CWP Villages		Control Villages		
	Test Group	CG1*	CG2	CG3	CG4
	Always/Usually Use CWP	Sometimes/ Never Use CWP	Always/Usually Boil Water	Sometimes/ Boil Water	Never Boil Water
Respondent data					
Sample size	61	40	26	23	51
Average household size	5.8	6.1	5.0	6.3	6.0
Average elapsed time since installation (months)	11.3	11.4	---	---	---
Water source					
% households that use					
Lined open wells	31%	63%	85%	96%	100%
Unlined open wells	10%	15%	8%	4%	0%
Ponds	44%	18%	12%	9%	18%
Rainwater	36%	10%	19%	9%	8%
Water Boiling					
% households that boil water					
Usually/Always	7%	2.5%	100%	---	---
Sometimes	3%	2.5%	---	100%	---
Never	90%	95%	---	---	100%
Incidence of diarrhea during the past month					
Percentage of households reporting no diarrhea cases	82%	65%	62%	30%	43%
Average number of diarrhea cases per household member (total and disaggregated by sex of household member)	0.17 M 0.21 F 0.13	0.32 0.46 0.18	0.30 0.48 0.17	1.11 1.11 1.11	0.59 0.63 0.55
Average diarrhea treatment cost per household member ($US)	0.14	0.38	0.28	1.52	0.72
Average number of missed school or work days per household member	0.07	0.30	0.35	1.66	0.90

* CG = Control Group

village was selected where CWPs had not been distributed. Selection of the control villages was based on proximity and on similarity in population, water sources, and socio-economic conditions. Within each control village, a list of households using ponds and open wells as their primary water source was compiled with the help of village leaders and residents. 100 respondents were selected randomly, 50 from each village list.

Out of the 101 CWP recipients surveyed in the two villages that had received CWPs, 40 had stopped using their CWPs regularly (reasons for stopping are discussed below). The presence of CWP recipients that had stopped using their CWPs prior to the survey provided an opportunity to define an additional control group. In Table 2, therefore, the CWP users in the pilot project villages are compared with the non-users in the same villages and with the non-users in the control villages. The non-users in the control villages are further subdivided based on their water boiling practices.

Rate of abandonment

It was found that 40 out of 101 households surveyed in the CWP villages had stopped using their CWPs regularly; five respondents reported that they used their CWP sometimes and 35 reported that they never used it. Out of the 35 never-users, 25 stopped when their plastic spigots broke and seven stopped when their clay filter elements broke. Other reasons, each given by one or two respondents, included a preference for boiled water, forgetting or being too busy to fill the CWP, a belief that the current water source is clean enough, inadequate water volume provided by the CWP, and an unwillingness to clean the CWP frequently. Factors that influenced the rate of abandonment include a weak plastic spigot (which has since been replaced by a more durable metal spigot), the unavailability of replacement clay filter elements during the pilot project, and the fact that the CWPs were distributed free of charge to the pilot project households, which may have resulted in a lower sense of ownership among recipients. Assuming that spigot breakage will not be a significant cause of CWP failure in the future, the abandonment rate can be estimated as 20% over a period of one year.

Incidence of diarrhoea

The survey used four indicators to measure the incidence of diarrhoea in the month preceding the survey: (a) the percentage of households reporting no cases of diarrhoea, (b) the average number of diarrhoea cases per household member, (c) the average cost for diarrhoea treatment per household member, and (d) the average number of school or work days lost due to diarrhoea per household member.

For all diarrhoea indicators, the Test Group (CWP users) reported better results than the Control Groups (CG). When compared to CG1 and CG2, which had the next best results, the Test Group had 17% to 20% more households reporting no diarrhoea, approximately half as many diarrhoea cases per person, one half to one third of the treatment expenses per person, and four to five times fewer work/school days missed per person.

CG1 and CG2 were almost identical in terms of diarrhoea indicators. The similarity between these two groups is surprising given that (a) CG1 includes mostly never-boilers and CG2 consists exclusively of usually/always-boilers, and (b) CG1 has a higher percentage of households using ponds and unlined open wells, suggesting that CG1 water sources are likely lower quality than CG2. Both of these factors would suggest that CG1 should have higher incidence of diarrhoea than CG2. It may be that the hygiene messages imparted during the pilot project (washing of hands and cups for instance) had a positive effect on the CG1 households, even in the absence of CWP use.

Another unexpected result was that the sometimes-boilers in CG3 had more incidence of diarrhoea than the never-boilers in CG4, despite a close similarity in the types of water sources used. The survey data did not reveal any obvious explanation for this result. Counter-intuitive results such as these point to the complexity of the relationship between environment, behavior, and health.

Despite these complexities, at least two conclusions can be drawn from the survey data:

- CWP users (Test Group) exhibited a lower incidence of diarrhoea than households in the same villages who did not use the CWP and who, for the most part (95%), did not boil their drinking water (CG1). This confirms that the CWP provides health benefits for households that initially practice no water boiling.
- In the control villages, where no CWPs were used, the households that usually/always boiled their drinking water (CG2) had a lower incidence of diarrhoea than the sometimes- and never-boilers in the same villages (CG3 and CG4). This confirms that water boiling leads to health benefits for households that that initially practice no water boiling.

The fact that CWP users (Test Group) had a lower incidence of diarrhoea than households in the control villages that usually/always boiled their drinking water (CG2) suggests that the CWP may be more effective than water boiling in the prevention of diarrhoea. However, this hypothesis is called into question by the observation that the difference in diarrhoea indicators between the usually/always boilers in the control villages (CG2) and the never boilers in the same villages (CG4), is similar in magnitude to the difference between the CWP users (Test Group) and non-CWP never-boilers in the CWP villages (CG1). Therefore, if the CG1 households began boiling their water, it is possible that they could achieve the same or even lower incidence of diarrhoea than the CWP-users, which would disprove the hypothesis. Since there was not enough data to compare CWP-users to always-boilers without CWPs in the same CWP villages, it is not possible to determine with certainty the relative effectiveness of the CWP and water boiling in the prevention of diarrhoea. Similarly, it is not possible to predict whether

CWP use will result in health improvement for households that are already boiling their drinking water. This question should be the subject of future studies.

The gender breakdown of diarrhoea cases per household member (Table 2) indicates that male household members suffered a greater number of diarrhoea cases in all study groups, except CG3, in which male and female cases were equal. When compared with CG1 and CG2, the use of the CWP by the Test Group resulted in a reduction of approximately 55% in male diarrhoea cases and a reduction of approximately 26% in female diarrhoea cases.

Other impacts

In addition to the Control Group Comparison survey described above, another survey was conducted in which all 1,000 recipient households were interviewed prior to receiving their CWP (baseline) and after three months of use. The Baseline and Third Month survey gathered information on water-related expenses, water treatment practices, and user satisfaction.

Households that boiled their drinking water prior to using the CWP saved time and expenses related to water boiling. Sixty-nine percent of recipient households boiled water 'always' or 'sometimes' prior to using the CWP. Almost all stopped boiling after using the CWP. Most water-boilers (89%) collected their firewood themselves and saved 22 hours per month in time spent gathering firewood and boiling water. Those water-boilers that purchased firewood (11%) saved an average of US$1.40 per month in firewood expenses and approximately 16 hours per month in time spent boiling water.

Ninety-five percent of households reported a high degree of satisfaction with the CWP saying that it produced good tasting water, was easy to maintain, and was important to the family because of health benefits and elimination of the need to boil water. Households typically fill the CWP two to three times per day producing 20 to 30 litres of clean water, which was adequate for the daily drinking needs of households with up to nine people (average household size was 5.8). More than one-third of households reported having enough water for additional uses including cooking, vegetable washing, and face washing.

Many of the CWP impacts were biased toward improving the situation of women. Women are the primary beneficiaries of time saved in water boiling and care of sick family members. Since women in Cambodia are usually the managers of daily household expenses, they also benefit directly from money saved on purchases of water, firewood, and medications.

Conclusions

This field study found that the CWP performed well under conditions of rural household use. Ninety-nine percent of the filters produced water meeting or exceeding WHO guidelines for 'low risk' rural water supplies. Households that used the CWP experienced health improvements and savings in time and expenses relative to control groups that did not use the CWP. Users also expressed satisfaction with the technology including water taste, ease of use, and adequacy of the volume produced. These outcomes were a result of both the technology and the accompanying training and hygiene education, which was an important component of the field trials.

Approximately 20 percent of CWP recipients stopped using their CWPs regularly within the first year of use. This rate of abandonment can likely be decreased by making replacements filter elements available in local markets and by charging recipients for a portion or the full cost of the CWP.

The low production cost makes full-cost CWPs affordable for a significant portion of the rural population. Consequently, it is envisioned that the CWP can be made widely available in rural areas through a network of private small-scale manufacturers and distributors. An appropriate role for public funds in this case is to facilitate development of the private-sector production and distribution system, support the health and hygiene education component that must necessarily accompany the CWP distribution, and finance social marketing campaigns to raise awareness and create initial demand for the CWP. Such a strategy would enhance long-term sustainability by ensuring on-going availability of new and replacement CWPs through self-financed market channels. Work to establish such a private-sector supply chain has begun in Cambodia.

Another appropriate area for public investment is in continued research and development of domestic point-of-use water treatment technologies. A comparative analysis of different options (boiling, chlorination, sand filtration, and solar disinfection, to name a few), including field assessments of health impacts, would provide valuable information. For the CWP, a number of questions remain to be answered. The physical and chemical mechanisms by which the CWP functions are not well understood and warrant further study. CWP lifespan and optimum flow rate need to be better defined. Methods for producing and applying silver to the ceramic media also require further development.

References

Lantagne, Daniele S. (2001), Investigations of the Potters for Peace Colloidal Silver Impregnated Ceramic Filter, Report 1: Intrinsic Effectiveness, Alethia Environmental, Allston MA, USA.

World Health Organization (1997), Guidelines for Drinking-Water Quality, Volume 3: Surveillance and control of community supplies, Second Edition, Geneva, p. 78.

World Health Organization (2003), Statement on the Establishment of an International Network to Promote Safe Household Water Treatment and Storage, Geneva, February 25, 2003

Notes

1. Field trials were conducted by an NGO, International Development Enterprises (www.ide-international.org),

with financial assistance from the Canada-Cambodia Health & Nutrition Initiatives Fund supported by the Canadian International Development Agency.

2. US$5.50 is the factory-door production cost for the complete CWP set including filter element, receptacle, spigot, lid, and instruction brochure. The cost includes materials, labor, factory rent and utilities, factory management, depreciation on production equipment, packaging, publicity, and an allowance for filter elements rejected during manufacture or broken during transport. The cost does not include tax, transportation, manufacturer's profit, or distributor's profit.
3. Risk categories used in this report are defined according to World Health Organization guidelines for rural water supplies: zero E. coli = conforms to WHO guidelines; 1 to 10 E. coli per 100 ml = low risk; 10 to 100 = intermediate risk; 100 to 1000 = high risk; and more than 1000 = very high risk (WHO, 1997).
4. Water-source disaggregated values in Table 1 were adjusted to the benchmark time of 3.7 months (the average elapsed time for the entire sample) using the relationship illustrated in Figure 2. No time correction was needed for the gender disaggregated values since the average elapsed time of both the male- and female-headed household groups was approximately equal to the benchmark time.

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