Water and hygiene interventions to reduce diarrhoea in rural Afghanistan: a randomized controlled study

Melissa C. Opryszko, Sayed Waheedullah Majeed, Peter M. Hansen, Jessica A. Myers, Duza Baba, Richard E. Thompson and Gilbert Burnham

ABSTRACT

A randomized controlled trial of four interventions was conducted using tubewells ($n = 2,486$), liquid sodium hypochlorite ('Clorin') distributed with an improved water vessel ($n = 2,305$), hygiene promotion ($n = 1,877$), and a combination of the three ($n = 2,040$) to create an evidence-base for water policy in Afghanistan. A fifth group served as a control ($n = 2,377$). Interventions were randomized across 32 villages in Wardak province. Outcomes were measured through two household surveys separated by one year and twice-weekly household surveillance conducted over 16 months. The households receiving all three interventions showed reduction in diarrhoea compared with the control group, through both longitudinal surveillance data (IRR [95% CI] = 0.61 [0.47–0.81]) and cross-sectional survey data (AOR [95% CI] = 0.53 [0.30–0.93]). This reduction was significant when all household members were included, but did not reach significance when only children under five were considered. These results suggest multi-barrier methods are necessary where there are many opportunities for water contamination. Surveillance data suggested a greater impact of interventions on reducing diarrhoeal diseases than data from the surveys. Higher economic status as measured through household assets was associated with lower rates of diarrhoea and greater intervention uptake, excepting Clorin. Use of soap was also associated with lower prevalence of diarrhoea.

Key words | Afghanistan, Clorin, hygiene education, randomized controlled study, rural water supply, water and sanitation

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INTRODUCTION

Two decades of conflict have left the people of Afghanistan with poor health status and a heavily damaged infrastructure. Among Afghans, 22% of the total population, 37% of the urban and 17% of the rural population are estimated to have access to drinking water from improved sources such as boreholes, protected wells and piped water (UNICEF 2009). Sources commonly used for drinking water by Afghans include shallow wells and surface water that are vulnerable to faecal contamination. Afghanistan is among the most water scarce countries in the world (UNDP 2004). In addition, UNICEF (2009) estimates that 70% of the total

population lack adequate sanitation. A 2001 study in Faryab Province found 25% of deaths across all age groups were associated with diarrhoea while diarrhoea was present in 30.5% of deaths of children less than five years and in 40% of deaths in children five to nine years old (Assefa et al. 2001). Other studies in Afghanistan have placed the two-week prevalence of diarrhoea between 20 and 50% for children under five resulting in an estimated 85,000 annual childhood deaths (UNDP 2004; UNICEF 2006a). World-wide, unsafe water, poor hygiene and uncontrolled faeces disposal are thought to contribute to about 1.5 to 1.8 million

deaths of children each year (UNDP 2006; UNICEF 2006*b*). Repeated bouts of diarrhoea can contribute to stunting and wasting. In Afghanistan this is an important risk as it is estimated that 49% of children under five are underweight, 50% are stunted and 10% are wasted (UNDP 2004).

This study was undertaken in Wardak province from May 2005 through September 2006 to provide an evidence base for diarrhoea reduction policies in rural Afghanistan. The primary study hypothesis was that villages randomized to receive interventions would have a reduction in diarrhoea greater than that of villages randomized to the control group. Funding was provided by the Ministry of Public Health (MOPH) of the Islamic Republic of Afghanistan.

METHODS

Design

This study measured the effectiveness of three individual interventions and the joint effect of the three to reduce household diarrhoeal diseases. Diarrhoea was defined as three or more loose or watery stools in the previous 24 hours in accordance with the MOPH definition. Additionally, a household was defined as the group of people who ate together the previous evening.

The study was designed with 400 households in each of four intervention groups and a control group. This sample size was adequate to detect a 20% change in both diarrhoeal incidence and prevalence, assuming a 5% weekly incidence for children under five. The study assumed a design effect of two and an average household size of six.

The interventions tested were: (1) liquid sodium hypochlorite ('Clorin') produced in Afghanistan and marketed along with an improved water vessel and training on proper use; (2) hygiene education ('Hygiene'); (3) improved tubewells ('Wells'); and (4) all three interventions together ('All'). Each of these interventions has been shown to be effective in reducing diarrhoea in studies elsewhere (Esrey *et al.* 1991; Mintz *et al.* 1995; Quick *et al.* 1999; 2006; Curtis & Cairncross 2003; Luby *et al.* 2004; Fewtrell *et al.* 2005; Clasen *et al.* 2006), but there is little evidence regarding their level of effectiveness in Afghanistan. Diarrhoea was also measured in a control population ('Control').

Clorin

This liquid point-of-use disinfectant developed by the Pan American Health Organization (PAHO) and the Centers for Disease Control and Prevention (CDC) is a 0.05% sodium hypochlorite solution produced through electrolysis. Previous studies have suggested that Clorin, along with an improved water vessel and instructions on proper use, could reduce diarrhoea prevalence by 15–48% (Quick *et al.* 1999). At the time of the study social marketing of Clorin had recently begun in Afghanistan supported by the United States Agency for International Development (USAID). Clorin is intended for household uses and leaves a chlorine residual (Macy & Quick 2002; WHO 2002; Wright *et al.* 2004). A bottle of Clorin is expected to treat enough drinking water for a household of six for one month (PSI 2005). Each bottle of Clorin was labelled with illustrated and written instructions, translated into the local languages of Pashto and Dari, on the proper use of the product. A pamphlet outlining instructions on the proper use of Clorin through illustrations and text was also distributed to each household receiving Clorin. Additionally, the Clorin bottle cap was marked for measuring appropriate doses for treating either 10 litres or 20 litres of water. A 20-litre plastic vessel was distributed with Clorin that had a narrow mouth, tight-fitting lid, spigot and markings at 10 and 20 litre volumes. Educators, in teams of one male and one female, visited 'Clorin' and 'All' households twice in the summer of 2005 with approximately one month between visits.

Clorin was delivered monthly to study households from June 2005 through September 2006. Population Services International (PSI) supplied Clorin and improved water vessels as well as the training of Clorin educators for the study interventions. Management Sciences for Health, and COMRI-A assumed Clorin production and distribution in Afghanistan in 2006.

Hygiene education

Hygiene plays an important role in diarrhoeal disease transmission, with numerous studies demonstrating the association between poor hygiene practices and increased risk of diarrhoea (Knight *et al.* 1992; Gorter *et al.* 1998;

Luby *et al.* 2004). As a result of high diarrhoeal disease rates in Afghanistan, hygiene education has become a regular feature of many Afghan health projects but there is little data on the effectiveness of these projects (MOPH 2001; UNICEF 2006*a*).

The study utilized a hygiene education curriculum produced by PSI and USAID. Hygiene education messages were communicated through pictures printed on large cards and accompanied by spoken hygiene messages on safe water practices relating to five key messages:

1. Use protected drinking water
2. Improve environmental sanitation; use and maintain latrines
3. Improve personal hygiene, especially hand washing practices
4. Protect food from contamination
5. Use oral rehydration therapy (ORT) for diarrhoea.

Teams of PSI-trained educators delivered these messages in house-to-house visits lasting approximately 30 minutes each. Each team consisted of one male and one female. Teams focused the messages to adult women in each household because women in Afghanistan are generally responsible for household water supplies and hygiene behaviours (Klijn 2002). The teams visited households in the 'Hygiene' and 'All' groups twice during the summer of 2005 with approximately one month between each visit.

Improved wells

Wells were constructed by local contractors primarily using percussion equipment. The Danish Committee for Aid to Afghan Refugees (DACAAR), which has managed water projects in Afghanistan since 1998, oversaw and coordinated all well construction. In a few villages diamond-tipped rotary drills were needed because of the geology of the rock underlying some villages. The new tubewells were placed in order to provide approximately one well per 25 households, with each well providing at least 25 litres/person/day, the Afghanistan national standard (Government of Afghanistan 2004*a*). An engineer worked with each community to establish agreement for well sites. Tubewells were sited to ensure community ownership, accessibility for women and adequate distance from sources of contamination such as

latrines, livestock and other waste sites. In one village, a non-functioning existing tubewell was repaired instead of constructing a new one. All villages agreed to support post-construction well maintenance.

All three interventions

Villages in this study group received all three interventions implemented in the same way as individual interventions, and implemented simultaneously.

Control

Villages randomized to the control group did not receive any active intervention. At the end of the study, all villages that did not receive new tubewells as part of their intervention had new wells installed.

Changes to study design

Interventions began in June 2005 and were expected to be fully implemented by the end of July 2005, with data collection to continue until the end of September 2005. Completion of the wells within the two-month implementation period was not possible. Difficulties experienced during the study included lack of water-bearing rock strata and the need for scarce rotary drilling equipment to penetrate the rock. Additional barriers included violent attacks and intimidations against well-drilling staff and participating villages from insurgents outside the communities who threatened study sites. Because of these multiple difficulties encountered during well construction, the study was extended by one year to allow additional time to construct wells. Well drillers were unable to complete wells in one village that was randomized to 'Wells' and one village randomized to 'All'.

Study population and sampling

Wardak Province, west of Kabul, was chosen as the study site because of its large rural population, high prevalence of diarrhoea, lack of improved water sources, accessibility to Kabul-based staff and relative security at the project start. The estimated population was 413,000, with 99% living in rural areas (Government of Afghanistan 2003). National

population indicators consisting of statistics on health, environment, education and women's status ranked Wardak 7th highest of 34 provinces (UNICEF 2006*a*). In a 2004 health facility catchment survey, prevalence of diarrhoeal diseases in the preceding 30 days in Wardak was 34% for children under five and 12% across all ages. In the same survey, the national prevalence rates for diarrhoeal diseases in the preceding 30 days were 43% for children under five and 25% for all ages (Government of Afghanistan 2004*b*). Within Wardak, Sayadabad District was selected as the project site based on a 2004 DACAAR survey that found 76% of Sayadabad's villages lacked adequate improved water sources to meet government standards of one protected water source per 25 households (DACAAR 2004). Villages identified for this study had less than one improved water source per 50 households.

Thirty-four villages were systematically randomized into one of five study groups to ensure comparability between intervention groups. The sampling frame first stratified villages by need for improved water, as measured by surface water usage reported in the 2004 DACAAR survey, and then by population size, as reported by village elders. Each of the five intervention groups was then assigned a number from one to five. A random starting number from one to five was assigned to the village at the top of the list while the next village on the list was assigned the next sequential number. The assignment of intervention groups followed in numerical order, cycling through the five numbers corresponding to the five intervention groups until all villages were assigned to an intervention group. Village locations within the project area represented a variety of environmental conditions including fertile river valleys, rocky hilltops and flat plateaus, with the majority of sites being arid. Only one intervention group was initiated in any village or geographically separated portion of a village in order to limit crossover between interventions.

The number of households enrolled from any one village ranged from 11 to 120 households. In villages smaller than 120 households, all households were asked to participate. In villages larger than 120 households, a random start was used to select four groups of 30 households each. Enrolled households agreed to adhere to the study protocols and the intervention to which they were randomized, including obtaining water from specific sources, chlorinating domestic water, reporting to the survey team information on household diarrhoea as requested, and agreeing to not resell supplies provided to the household.

Adjustments in study population

The project was intended to be entirely located in Sayadabad; however, inaccurate maps resulted in several villages in neighbouring Chak District being included in the study (Figure 1). Two villages were excluded after randomization but before data analysis when existing protected wells were discovered; therefore 32 villages were included in the data analyses. Also, two villages overlapped with an intensive sanitation and hygiene project implemented by an NGO, one village mistakenly received new tubewells in addition to their intended intervention of hygiene education and two villages were not able to have new wells completed.

Data collection

Outcomes were measured through cross-sectional household surveys conducted in May 2005 and May 2006 to measure changes in diarrhoea prevalence and longitudinal twice-weekly household surveillance from June 2005 through September 2006 to measure diarrhoea incidence. A household census was conducted in the summer of
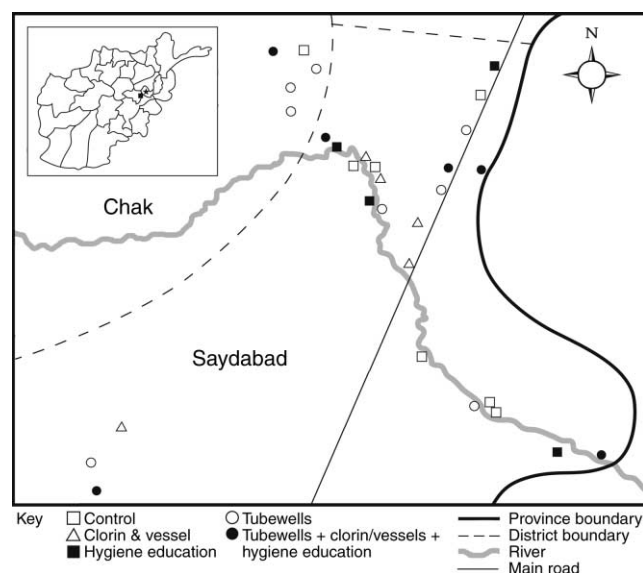

Figure 1 | Study site, Wardak province, Afghanistan.

2005 and again at the end of September 2006 to determine the total population at risk for disease. Results presented here represent 17 months of continuous data collection (Figure 2).

Cross-sectional data

Sixteen surveyors were trained for the baseline survey while 20 surveyors were trained for the follow-up survey. Training lasted two days for each survey. Survey instruments were translated into Pashto and Dari and field-tested within Kabul while all surveys actually administered in Wardak were conducted in Pashto, the dominant language of that region. Surveyors worked in pairs with one female and one male in accordance with local customs. Information from the primary adult female caregiver was sought as the most reliable source of information on diarrhoea occurrence and water handling within the household (Klijn 2002). Surveys collected data on household demographics, hygiene, water collection, water storage and diarrhoeal disease occurrence along with observations of water storage, hand washing facilities and sanitation. The follow-up survey contained questions and observations similar to the baseline along with questions on household assets and adult education levels. Field supervisors monitored survey data collection daily.

Surveillance data

The surveillance data was collected mainly by community health workers (CHWs) who were assigned to collect data in villages away from their home villages. Where community health workers were not available, personnel from local health clinics were employed as data collectors. For cultural reasons female data collectors could only work in the company of male relatives. Of the 20 disease surveillance teams, two were unable to locate females available to work outside their homes and the resulting teams were all male.

Surveillance data consisted of diarrhoea and bloody diarrhoea occurrences for all household members and was collected from households twice each week. Field supervisors checked surveillance data twice monthly. Unannounced monitoring by field staff was conducted at least three times in all project villages.

Missing data that could not be verified or referenced from existing data was left as missing, with no imputation of missing data. Chlorine residuals in the 'Clorin' and 'All' groups were randomly checked throughout the study period by surveillance data collectors and field supervisors using LaMotte Insta-Test3 strips (LaMotte Company, Chestertown, Maryland).

Data analysis

Cross-sectional data

To investigate the effects of the interventions on diarrhoea prevalence, logistic regression models were used to estimate adjusted pre-post odds ratios comparing the odds of diarrhoea at the follow-up survey with the odds of diarrhoea at the baseline survey in each intervention and control group, as well as ratios of odds ratios comparing the pre-post odds ratio in each intervention group with the pre-post odds ratio in the control group. Household variables found to be associated with diarrhoea prevalence at baseline were included in the final models along with an economic status indicator derived from the assets index to adjust for potential confounding.
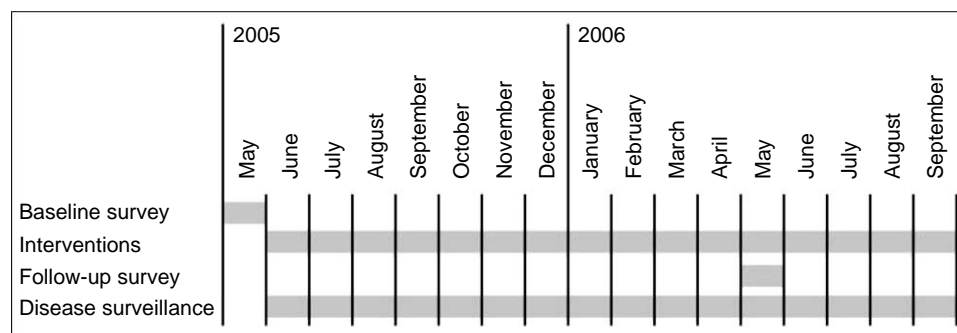

Figure 2 | Timeline of activities.

The analysis was done with both household and individuals within the household as the units of analysis. In addition, clustering was considered by village and by household for the household-as-unit-of-analysis and individual-as-unit-of-analysis, respectively, using the Huber–White sandwich estimators for the variance (Froot 1989). Baseline data was entered in Microsoft Excel in Kabul with each entry checked for accuracy by a second person. The follow-up survey data was double entered in CSPro (US Census Bureau free software) in Kabul. Data from both surveys was analysed in Stata 9.2 (StataCorp, College Station, Texas) in Kabul and Baltimore.

Asset index

Questions about household assets were added to the follow-up survey. The household assets score was developed from principal component analysis of Wardak provincial data in the 2004 National Community Health Feedback Assessment (NCHFA) (Government of Afghanistan 2004*b*) and used the following formula:

Household asset score = [(value of asset variable – unweighted mean of asset variable)/unweighted standard deviation of asset variable] × 'raw' asset factor score (Gwatkin *et al.* 2000).

Individual standardized scores were generated for each household asset based on ownership. The standardized household asset scores were added to create a total household asset score. Households were ranked and then divided into five quintiles. The household asset scores and the quintile cut off points were then applied to the database to generate a household asset index (Vyas & Kumaranayake 2006). The 2004 NCHFA Wardak sample was used as the reference. The households were then classified by asset ownership based on general clustering of scores into three groups: the poorest 40%, middle 40% and least poor 20%.

Surveillance data

Incidence rate ratios were used to investigate the effects of the interventions on diarrhoea incidence between intervention and control groups. Owing to the delays in well construction, data analyses focus on the four-month period of June–September 2006 when all interventions had been completed to the extent possible. For each household visit during that time, a person was considered to have an incident case of diarrhoea if: (1) he or she was recorded as having diarrhoea at that visit; and (2) he or she did not have diarrhoea at the visit immediately preceding it. Because the population within each village fluctuated over the course of the study, total person-time under surveillance was calculated using an estimate of average village population during the study period, for which the mean of the population count in the surveillance data and the count in the follow-up survey was used. At-risk person-time within each village was calculated by multiplying the average population estimate by the number of weeks under surveillance (17.3) to get total person time, and then subtracting out the person-time not at risk for an incident case of diarrhoea, which was the time between study visits following a positive assessment of diarrhoea summed across individuals in the village. Finally, for each village, the total number of incident cases was divided by the total at-risk person-time to obtain the village level incidence rates. Intervention group incidence rates were the population-weighted mean of the village level incidence rates. The population number used is the mean of the surveillance and post-survey numbers.

Monthly prevalence of diarrhoea was also estimated in each intervention group for the entire June 2005–September 2006 study period, by dividing the number of individuals with reported diarrhoea at any point during the month by the estimated population. Disease surveillance data was entered in Microsoft Excel in Kabul, with each entry checked for accuracy by a second person and analysed using R software (GNU Project free software) in Baltimore.

While the original randomization to study groups was kept for the primary analyses, sub-analyses were also conducted excluding the five villages that did not received interventions as prescribed by the randomization. The study was designed to examine effectiveness of interventions rather than efficacy. Intention-to-treat analysis was used to retain original randomization for all primary analyses (Hollis & Campbell 1999).

Ethical approval

Free and informed consent of the participants or their legal representatives was obtained and the study protocol was

approved by the Institutional Review Board of the Ministry of Public Health of the Islamic Republic of Afghanistan in Kabul (#357705, approved 10 April 2005) and by the Johns Hopkins Bloomberg School of Public Health, Institutional Review Board, Maryland, USA (#H.22.04.12.21.A2, approved 28 February 2005). All interventions were provided to study households at no monetary cost. Permission to conduct the study within the region was received from local, district and provincial leaders. No village refused to participate.

RESULTS

Baseline data

Twenty-five households refused participation at baseline, 1.6% of the total households visited. Household populations reported by village leaders were consistently higher than actual populations found during the study. Expected enrolment was 400 households per study group while actual enrolment ranged from 279 to 330 households per study group at baseline. The distribution of participants by intervention is shown in Figure 3.

The baseline survey population of 1,514 households had a mean household size of 7.3 (sd 3.7). Diarrhoea within the previous two weeks at baseline was 6.4% [95%CI, 6.0%, 6.9%] of the total study population and 22.1% [95%CI, 20.2%, 24.0%] of children under five years of age (Table 1).

While the primary female caretaker in the household was sought out to participate in the survey, in 49% of households males were the respondents following household refusal to allow females to participate. The study population was primarily long-time residents; 97% of households had lived in the village before 2002. School had been attended by 36% of males and 7% of females interviewed. Water was treated by 7% of households, with boiling the most common method. Less than 1% of households treated water with Clorin prior to study interventions.

Reported use of soap for washing the body was protective against diarrhoea for children under five (OR [95% CI] = 0.77 [0.60, 0.98], $p = 0.03$) as was washing hands with soap located in or near the kitchen/food preparation area protective for children under five (OR [95% CI] = 0.58 [034, 1.00], $p = 0.05$). Washing hands in the food preparation area also statistically decreased the likelihood of diarrhoea prevalence in the total population (OR [95% CI] = 0.66 [0.44, 0.99], $p = 0.04$); however only 6% of the households were observed to have hand washing provisions available in or near the kitchen. Soap was reported as available for hand washing by 77% of households while 55% were actually observed to have soap readily available. Additionally, 62% of households reported hand washing facilities near their latrines but only 25% were observed to have hand washing facilities present near latrines.

Unprotected hand-dug wells were used by 35% of households as their primary water source at baseline. On average, households collected 25.5 litres of water/person/day, with approximately 31 minutes needed for collection. Local key informants stated that persons over age 12 use approximately 5 litres of water/day for ablutions as part of religious practices.

Eighty per cent of the households had latrines and half of these were shared with one or more other households. Of the latrines, 23% had faecal matter outside of containment areas and open defecation was in evidence outside compound walls throughout the study area. Faecal material was often observed draining from the back of latrines into pathways or open ground. Analysis of baseline data showed an increase in the odds of diarrhoea for those under five (OR [95% CI] = 1.60 [1.14, 2.22], $p < 0.01$) and the total population (OR [95% CI] = 1.64 [1.16, 2.32], $p < 0.01$) for households with a latrine.

Follow-up data

At follow-up, approximately 10% of the study households could not be located, primarily because of migration and the combining of households. Comparative analyses were performed with 1,514 households surveyed at baseline and the subset of 1,359 households found at follow-up to determine whether a systematic bias occurred among households lost to follow-up. Proportions of responses to the baseline survey were generally found to be less than 5% different with no systematic bias detected.
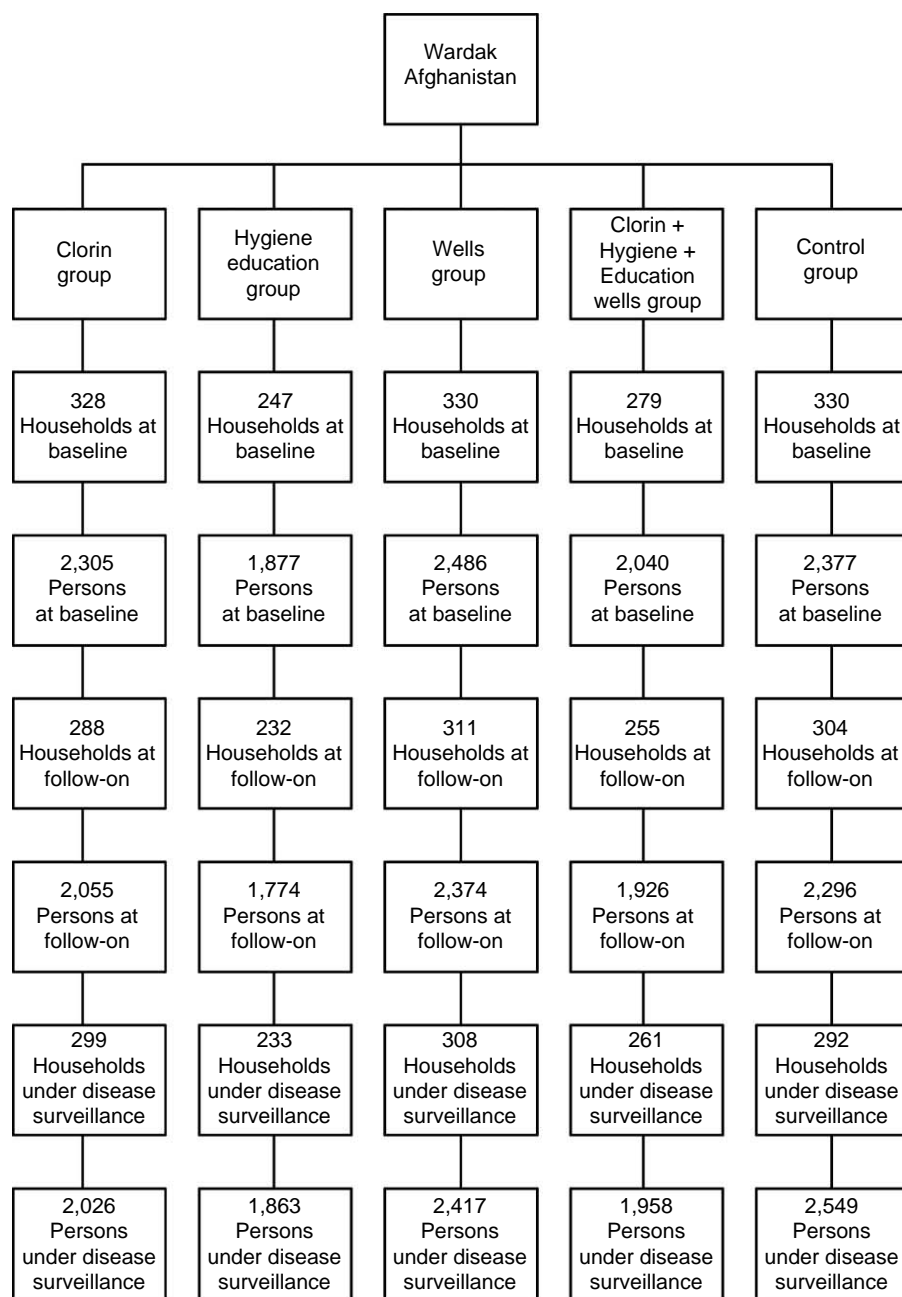
Figure 3 | Allocation of study population by intervention group.

The follow-up survey population showed a two-week diarrhoea prevalence in children under five of 25.0% [23.0%, 27.1%]. Although diarrhoea prevalence increased in all age groups at the time of the follow-up survey, the proportion of reports with dysentery decreased at the follow-up.

The group of villages receiving the 'All' intervention was the only group that was found to have lower diarrhoea

prevalence in the follow-up compared with the baseline. This was for both children less than five years of age and the total population (Figures 4 and 5).

Changes in self-reported water and hygiene-related behaviours were also examined. Across the total study population, 7% of households reported treating water during the last two weeks at baseline which increased to

Table 1 | Diarrhoea and dysentery two-week prevalence [95% CI] at baseline (1,514 households) and follow-up (1,359 households) by population age

| Age group	Baseline			Follow-up		
	n (cases of diarrhoea)	Diarrhoea prevalence during last 2 weeks (%)	% Diarrhoea which was bloody during last 2 weeks	n (cases of diarrhoea)	Diarrhoea prevalence during last 2 weeks (%)	% Diarrhoea which was bloody during last 2 weeks
<1 year	270 (56)	20.7 [16.1, 26.1]	16.1 [7.6, 28.3]	254 (53)	20.9 [16.0, 26.4]	5.7 [1.2, 15.7]
<5 years	1,967 (435)	22.1 [20.2, 24.0]	26.2 [22.1, 30.6]	1,750 (437)	25.0 [23.0, 27.1]	8.0 [5.6, 11.0]
>5 years	9,118 (276)	3.0 [2.7, 3.4]	32.2 [26.8, 38.1]	8,675 (365)	4.2 [3.8, 4.7]	18.4 [14.5, 22.7]
Total population	11,085 (711)	6.4 [6.0, 6.9]	28.6 [25.3, 32.0]	10,425 (802)	7.7 [7.2, 8.2]	12.7 [10.5, 15.2]

38% at follow-up. Self-reported use of Clorin during the previous two weeks increased across all groups from baseline to follow-up with households reporting the following proportional usage: 82% in 'Clorin' group; 78% in 'All' group; 11% in 'Wells' group; 4% in 'Hygiene' group and 5% in 'Control'. Among only those households that reported treating water in the past two weeks, Clorin was the method of treatment for the following proportion of households: 99% of the 'Clorin' group; 98% of the 'All' group; 76% of the 'Wells' group; 52% of the 'Hygiene' group and 47% of the 'Control' group. Chlorine residuals were not checked during surveys so these results were not confirmed.

Protected tubewells were utilized as the principal source of water in 34.7% of 'Wells' households and 47.1% of 'All' households at follow-up, increasing from baseline values of 7.6 and 2.2%, respectively. Sub-analysis of those villages receiving adequate tubewell coverage (i.e. excluding intervention villages where new tubewells were unable to be completed as intended) showed utilization of protected tubewells increased to 41.2% in the 'Wells' group and 56.5% in the 'All' group. Protected tubewell use also increased from 2.5 to 11.8% in the 'Clorin' group, 3.2 to 31.5% in the 'Hygiene' group and 6.8 to 25.3% in 'Control' households.

Hygiene households showed an increase in self-reported use of soap for hand washing in the last 24 hours from 37.9 to 80.9%, while self-reported hand washing facility availability in the kitchen rose from 9.8 to 17.2%. Behaviours which did not improve after the 'Hygiene' intervention included observed facilities for hand washing availability near the latrine, which decreased from 31.7% at baseline to 2.1% at the follow-up, and the proportion of households observed with faecal matter outside the latrine containment area rose from 20.1 to 32.5%.

Variables chosen for the multilevel model were those that were significantly associated with diarrhoea prevalence in the univariate analyses, including: economic status measured by the household asset score; age of person interviewed; whether the principal wife was interviewed or not; total household size; education level of the principal female (some versus none); education level of the principal male (some versus none); presence of a latrine for household use; and usual hand washing practices in the kitchen or food preparation area (yes versus no).

The 'All' group was the only intervention group to show either a significant reduction or approaching significant reduction in the odds of diarrhoea prevalence over time compared with the 'Control' group in adjusted logistic regression analyses. With household as the unit of analysis, children under the age of five experienced an approximate 11% proportional reduction in diarrhoea prevalence at the follow-up survey compared with baseline in the 'All' group, while children under five years in the 'Control' group experienced an approximate 45% proportional increase in
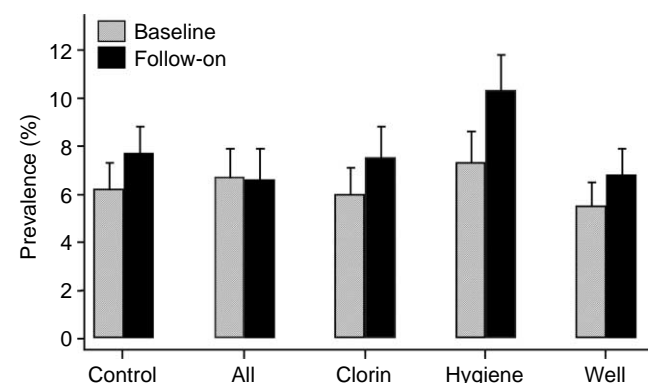
Figure 4 | Diarrhoea prevalence in all ages in the past two weeks (95% CI) at baseline and follow-up survey.
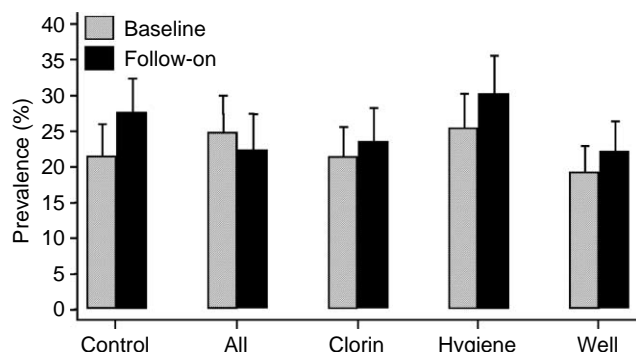
Figure 5 | Diarrhoea prevalence in children under five in the past two weeks (95% CI), in baseline and follow-up surveys.

diarrhoea prevalence, resulting in an approximate 40% reduction in the odds of diarrhoea prevalence increasing over time for children in the 'All' group compared with the 'Control' (AOR [95% CI] = 0.61 [0.36, 1.04], $p = 0.07$). Similar results were found for children under age 5 when the individuals were used as the unit of analyses. Among children in the 'All' group, a 37% reduction in the odds of diarrhoea prevalence increasing over time was found when compared with children in the 'Control' group (AOR [95% CI] = 0.63 [0.38, 1.06], $p = 0.08$). For all ages, a 47%

reduction in the odds of diarrhoea prevalence increasing over time was found when comparing the 'All' group with the 'Control' (AOR [95% CI] = 0.53 [0.30, 0.93], $p = 0.03$). No significant results were found in total diarrhoea prevalence for any other intervention group when the individual was considered as the unit of analysis. Results for each intervention group compared with the control are shown in Table 2.

Sensitivity analyses were performed on these findings by excluding the five villages where the intended interventions were not fully implemented. Findings were similar. Again, the 'All' group was the only group to show statistically significant results, with a 61% reduction in likelihood of diarrhoea for children less than five years (AOR [95% CI] = 0.39 [0.25, 0.61], $p < 0.001$) and a 50% reduction in the likelihood of diarrhoea in the total population of all ages (AOR [95% CI] = 0.50 [0.28, 0.89], $p = 0.018$).

Household economic status

Households in the poorest group were more likely to have higher diarrhoeal disease prevalence in every intervention

Table 2 | The adjusted odds ratios for difference in change in diarrhoea prevalence compared with the control group between baseline and follow on surveys

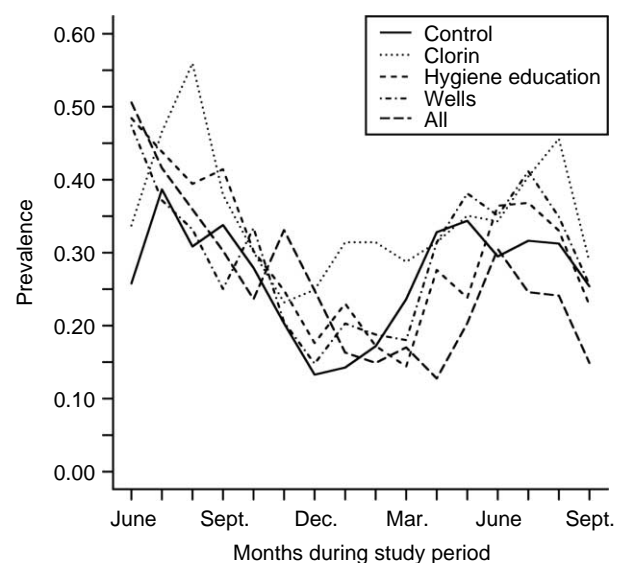| Group | House-holds | Household as unit of analysis | | | | Individual as unit of analysis | | | |
		AOR [95% CI] for change in diarrhoea prevalence	p	AOR [95% CI] for group differences in the change of prevalence	p	AOR [95% CI] for change in diarrhoea prevalence	p	AOR [95% CI] for group differences in the change of prevalence	p
Control	282								
<5		1.45 [1.04, 2.02]	0.03	–	–	1.35 [0.94, 1.92]	0.10	–	–
All ages		1.54 [0.89, 2.67]	0.12	–	–	1.23 [0.96, 1.57]	0.10	–	–
Clorin	287								
<5		1.16 [0.54, 2.53]	0.70	0.81 [0.35, 1.85]	0.61	1.20 [0.84, 1.69]	0.32	0.89 [0.54, 1.45]	0.64
All ages		1.21 [0.53, 2.75]	0.66	0.78 [0.30, 2.05]	0.62	1.24 [0.98, 1.59]	0.08	1.01 [0.72, 1.43]	0.95
Hygiene	231								
<5		1.09 [0.45, 2.62]	0.85	0.75 [0.29, 1.95]	0.56	1.21 [0.85, 1.73]	0.29	0.90 [0.54, 1.48]	0.68
All ages		1.48 [0.87, 2.52]	0.15	0.96 [0.45, 2.04]	0.92	1.29 [0.99, 1.68]	0.06	1.05 [0.73, 1.50]	0.80
Wells	304								
<5		1.22 [0.89, 1.69]	0.22	0.85 [0.54, 1.34]	0.48	1.22 [0.86, 1.74]	0.26	0.91 [0.56, 1.49]	0.70
All ages		1.41 [0.97, 2.05]	0.07	0.92 [0.47, 1.79]	0.80	1.27 [0.98, 1.65]	0.07	1.03 [0.73, 1.47]	0.85
All	255								
<5		0.89 [0.58, 1.36]	0.58	0.61 [0.36, 1.04]	0.07	0.85 [0.58, 1.25]	0.41	0.63 [0.38, 1.06]	0.08
All ages		0.81 [0.67, 0.98]	0.03	0.53 [0.30, 0.93]	0.03	1.01 [0.77, 1.31]	0.97	0.82 [0.57, 1.17]	0.27

group and all ages except for children under 5 years in the Clorin group, when compared with households in the least poor group (Table 3). In this group the children under five in the poorest households had slightly lower diarrhoea prevalence than children under five in households in the least poor group. The disparity between the poorest and the least poor households was smallest in the Clorin group and largest in the 'All' group. The largest diarrhoeal disease prevalence differential between the poorest and least poor asset groups was found in children under five in households receiving all three interventions.

Disease surveillance results

Prevalence of diarrhoeal diseases in children under five fluctuated seasonally over the 16 month surveillance period, with clear peaks during each summer from June through September (Figure 6). Analyses of diarrhoeal diseases incidence from the surveillance data focuses on the four-month period from June through September 2006 when all interventions were in place to the extent possible. A reduction in the weekly diarrhoeal disease incidence in children less than five years of age during the four-month period was not significant in the 'All' group when compared
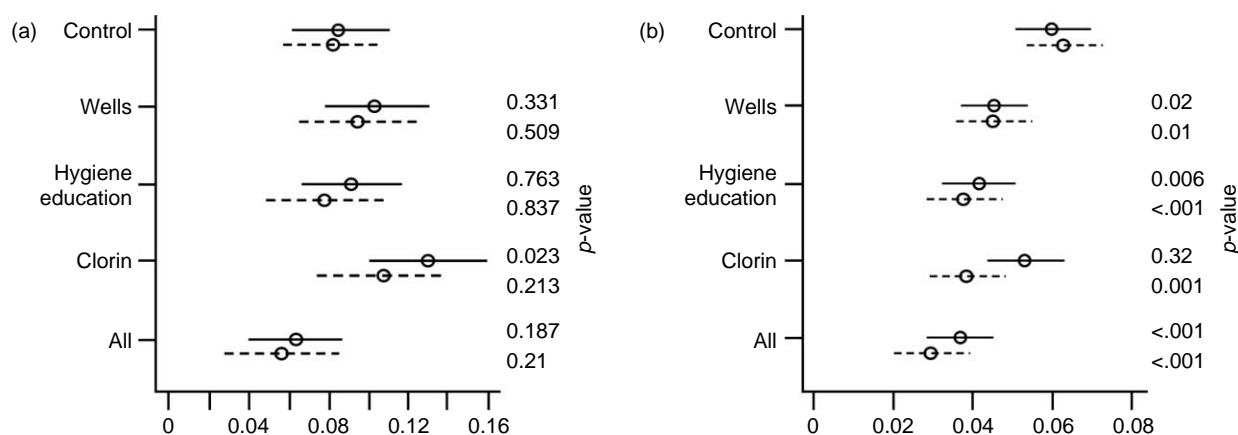

Figure 6 | Prevalence of diarrhoea among children under age five from surveillance data by month between June 2005 and September 2006 in the four intervention groups.

with the control ($p = 0.187$). Intervention groups other than the 'All' group did not show a reduction in diarrhoea incidence rates compared with the control group; however the Clorin group had a statistically significant increased rate of diarrhoea incidence. The weekly incidence rates for each of the intervention groups with point estimates and 95% confidence intervals are shown in Figure 7.

Analyses performed on household data from the four-month period in 2006 including all household members found a significant reduction in the incidence of diarrhoeal diseases in the 'Hygiene', 'Wells' and 'All' intervention groups compared with the Control group. The Clorin group showed a reduction in diarrhoea incidence that was only statistically significant when sensitivity analysis was performed excluding all five villages that did not fully receive interventions. The 'All' group had the largest overall reduction in diarrhoea incidence of 2.3 cases per 100 person weeks ($p < 0.001$), corresponding to a reduction in incidence rate of 39% (Table 4).

DISCUSSION

This, the first large-scale study of diarrhoea prevention in rural Afghanistan, presents longitudinal data from 10,813 people in 1,393 households and cross-sectional data on

Table 3 | Individual two-week diarrhoea prevalence [95% CI] at follow-up survey by presence of household assets

Intervention group	Poorest 40% households	Least poor 20% households	Low/high ratio
Control			
<5	29.8 [22.4, 38.1]	22.9 [15.7, 31.5]	1.30
All ages	9.7 [7.8, 11.9]	5.6 [4.1, 7.5]	1.73
Clorin			
<5	24.1 [17.7, 31.4]	26.2 [18.0, 35.8]	0.92
All ages	7.9 [6.2, 9.9]	8.3 [6.2, 10.8]	0.95
Hygiene			
<5	32.7 [24.1, 42.3]	29.2 [20.8, 38.9]	1.12
All ages	12.3 [9.7, 15.1]	7.7 [5.7, 10.2]	1.60
Wells			
<5	25.7 [19.4, 32.9]	17.9 [12.1, 25.2]	1.44
All ages	7.8 [6.2, 9.7]	5.2 [3.8, 7.0]	1.50
All			
<5	25.0 [18.2, 32.9]	15.7 [8.1, 26.4]	1.59
All ages	8.2 [6.4, 10.4]	5.6 [3.9, 7.8]	1.46

Figure 7 | Weekly diarrhoea incidence rates for (a) children under five and (b) total population from summer 2006 (June–September) and corresponding 95% confidence intervals by illness and intervention group. The solid line represents intention-to-treat analysis while the dashed line is a sensitivity analysis with five villages removed that did not fully receive the intended intervention.

1,390 households containing 10,395 persons. The finding at baseline that 22.1% of children under age five had experienced diarrhoea in the previous two weeks underscores the threat of diarrhoea to the health of young children in Afghanistan. The study's strongest conclusion is that, in poorly developed countries such as Afghanistan, no single intervention is adequate to interrupt diarrhoea occurrence in rural households. Programmes that seek to substantially reduce childhood diarrhoea should consider an integrated interventions approach.

It is likely that improved well water was contaminated at the time of collection through transport and storage vessels and introduction of microbial agents by unwashed hands and dirty utensils, as has been documented in other studies (Roberts *et al.* 2001; Jensen *et al.* 2002; Luby *et al.* 2004). Also, households assigned to study groups not receiving new tubewells may have travelled outside of

their villages to collect water from new wells in other study villages. This behaviour could account for the increase in the use of improved tubewells across all study groups thereby affecting comparisons between the groups.

The results from hygiene education alone demonstrated varying conclusions between the surveillance and survey data. The twice-weekly surveillance data provides evidence that hygiene education had an impact on the diarrhoeal disease incidence rates when all ages are considered. However, responses during the cross-sectional surveys conducted one year apart suggested an inconsistent uptake of the hygiene messages.

Clorin alone did not consistently lead to reductions in diarrhoea. This finding is similar to results of an earlier study in Zambia that found that inconsistent household use diminished Clorin's overall effectiveness (Olembo & Burnham 2004). In study villages, Clorin was found to be widely accepted among households and its effectiveness was not affected by low economic status. Additionally, there is evidence that suggests that Clorin use spread across the study area after the interventions began. This behaviour may have been impacted by ongoing marketing of Clorin as well as improved water vessels that occurred in the study region through summer radio campaigns and posters in local bazaars. However, Clorin's effectiveness may have been compromised by the use of turbid water. Household filtration, through cloth or other means, prior to the addition of Clorin may have improved outcomes

Table 4 | Diarrhoeal disease weekly incidence (cases per person-week) and incidence rate ratios (IRR) in total study population June 2006–September 2006

Intervention group	Diarrhoea incidence	IRR (95% CI)	p-value*
Clorin	0.053	0.89 (0.70–1.13)	0.32
Hygiene	0.042	0.69 (0.53–0.90)	0.006
Wells	0.045	0.75 (0.59–0.96)	0.02
All	0.037	0.61 (0.47–0.81)	<0.001
Control	0.060	–	–

*Comparison with control group.

(WHO 2002). In addition, there were some temporary quality control problems with Afghanistan-produced Clorin; however it is not thought that this problem persisted long enough to affect study outcomes.

Assessment of latrines found that few were located, constructed or maintained in a way that would limit environmental contamination. There was a suggestion from the study data (not shown) that the presence of a traditional elevated vault latrine in the household compound increased risk of diarrhoea among household members.

When households were classified by assets, as a proxy for wealth status, there was a substantial difference in diarrhoeal rates among children. This is particularly evident in the 'All' intervention households where children in the poorest households were more than twice as likely to have diarrhoea during the previous two weeks than children in the least poor households. While it is possible that better off households take up change more readily, it could also be that these households are located closer to improved water sources, and that they are more able to purchase adequate amounts of soap and other hygiene supplies. The asset scores also indicated that Clorin's use and/or effectiveness was not related to household economic status when provided free of charge. The Control group showed no difference in the likelihood of diarrhoeal disease occurrence between households of lower and higher economic status.

Data from twice weekly household surveillance showed more reductions in diarrhoea in intervention groups than the cross-sectional surveys that were separated by 12 months. Although results from both the cross-sectional surveys and the twice-weekly household surveillance visits give similar results, there were some inconsistencies. In places like rural Afghanistan with considerable seasonal and year-to-year fluctuations in diarrhoea prevalence, surveillance data, though a more demanding approach, is probably better suited to determine differences in events that are likely to fluctuate substantially. Further, it offers the chance to capture day-to-day contextual factors from the community which may not be detected by a cross-sectional study. The use of community health workers with their training and experience in working with communities offers further strengths to this type of community surveillance system.

Samples of source and household water supplies were analysed in existing Kabul labs but are not reported here because of the elevated error rates between 10 and 20% found during quality control procedures. Also, periods of instability limited the completion of water sample collection. However, water samples taken during the summer of 2005 support the conclusion of broad microbial contamination of both unprotected source water and household water supplies.

The delays in installing wells point to difficulties in extending well drilling programmes in countries such as Afghanistan where more remote, insecure and/or water scarce regions are often underserved. Well drilling programmes tend to focus on accessible and secure areas where water tables are close to the surface and wells can be sunk with simple percussion equipment (DACAAR 2005). The sampling frame for this study was largely made up of villages that had been bypassed in earlier well-drilling programmes. The study demonstrated that alternative approaches to improved water are required for some villages where percussion or even drilled wells are not an option. Additionally, even in a rural subsistence economy, household economic differentials may significantly affect programme outcomes.

An important lesson from this study is that field research is often possible in insecure settings, providing flexibility is incorporated into study design and analysis methods. Fragile states, especially those recovering from conflict, are in particular need of an evidence base for developing new policy and practice for national reconstruction.

Limitations

There were a number of potential limitations in this study. Recall of bouts of diarrhoea could affect findings from both survey and surveillance methods although recall is less likely to be a concern with twice-weekly data collection. However, adults may be less willing to reveal information about their own cases of diarrhoea and more likely to discuss children's cases. Insecurity and adverse weather conditions prevented Kabul-based staff from travelling to the field on a number of occasions, thereby limiting the ability to consistently monitor surveillance data collection.

Community health workers proved to be very effective data collectors, able to continue their work even as insurgents threatened the region. However, it was not possible to monitor their work as closely as planned.

Another limitation of the surveillance study is that person-time, used as the denominator for incidence rate calculations, was not observed perfectly and had to be estimated at the village level. Therefore, no adjustments for household level covariates were made, and all calculations were done using raw, unadjusted data. Additionally, intervention groups consisting of randomly assigned villages may have been significantly different prior to the interventions, which was not accounted for in the disease surveillance data analyses.

The different timing of intervention commencement may have affected an intervention's overall effectiveness, especially in the hygiene group. While hygiene educators visited households twice in the summer of 2005, the data analysis was primarily based on disease rates occurring between May 2006 and September 2006. It is possible that the hygiene group's peak effect may not have been measured owing to the lag time between the intervention and data collection periods.

Also, the intent of the study was to solicit household information from the principal female caregiver of a household, but approximately half of the time females were not permitted to give information or were unavailable. In most cases where the principal female was not interviewed, the male head of household provided responses. It is possible that information provided by females other than the principal female or males about diarrhoea occurrence in household members and children was not accurate.

The planned interventions could not be fully implemented in five villages for technical reasons, and this may have affected outcomes. For children under five, sensitivity analyses of surveillance data showed no change in our conclusions when data from these villages were excluded from the analyses. However, when diarrhoea among all household members was examined, excluding the five villages with incomplete implementation of interventions, Clorin as well as the other interventions was demonstrated to significantly decrease incidence of diarrhoea.

CONCLUSION

By comparing the effectiveness of interventions to reduce diarrhoea, this study found that substantial reductions in diarrhoeal disease rates in rural Afghanistan would best be obtained through multiple barrier methods incorporating tubewells, hygiene education and Clorin. The study also supports previous studies that found that hygiene education provided through direct and repeated contact with household members using targeted messages delivered by trained educators will reduce diarrhoeal disease rates. Tubewells were also shown to be important interventions for the reduction of diarrhoea but will require more sophisticated equipment, such as rotary drilling rigs, to construct new wells in more challenging mountainous regions. The addition of Clorin to the other interventions may pose a financial barrier to rural households, even at its subsidized price, as it was perceived to be too expensive. Households in the lower economic strata need to be targeted specifically as they carry more burden of diarrhoeal disease, and are least able to adapt to new interventions. Finally, the issues of improving design and use of effective latrines along with behaviour change interventions are critical, as it is likely that the current high rates of diarrhoea in Afghanistan may be very much influenced by faecal contamination from the commonly found elevated vault latrine.

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REFERENCES

Assefa, F., Jabarkhil, M. Z., Salama, P. & Spiegel, P. 2001 Malnutrition and mortality in Kohistan District, Afghanistan, April 2001. *J. Am. Med. Assoc.* **286**, 2723–2728.

Clasen, T., Roberts, I., Rabie, T., Schmidt, W. & Cairncross, S. 2006 Interventions to improve water quality for preventing diarrhoea (Review). *Cochrane Database Syst. Rev.* **3**, CD004794.

Curtis, V. & Cairncross, S. 2003 Effects of washing hands with soap on diarrhoea risk in the community: a systematic review. *Lancet Infect. Dis.* **3**, 275–281.

DACAAR 2004 Water and Sanitation Programme, Survey Report of Saydabad Wardak, December 2004. Kabul.

DACAAR 2005 Annual Report Kabul, http://www.dacaar.org/index.php?option=com_rokdownloads&view=file&Itemid=120&id=11:dacaar-annual-report-2005 (accessed 30 March 2010).

Esrey, S. A., Potash, J. B., Roberts, L. & Shiff, C. 1991 Effects of improved water supply and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma. *Bull. World Health Organ.* **59**, 609–621.

Fewtrell, L., Kaufmann, R. B., Kay, D., Enanoria, W., Haller, L. & Colford, J. M., Jr 2005 Water, sanitation, and hygiene interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis. *Lancet Infect. Dis.* **5**, 42–52.

Froot, K. A. 1989 Consistent covariance matrix estimation with cross-sectional dependence and heteroskedasticity in financial data. *J. Financ. Quant. Anal.* **24**, 333–355.

Gorter, A. C., Sandiford, P., Pauw, J., Morales, P., Pérez, R. M. & Alberts, H. 1998 Hygiene behaviour in rural Nicaragua in relation to diarrhoea. *Int. J. Epidemiol.* **27**(6), 1090–1100.

Government of Afghanistan 2003 National population by age group. Central Statistics Office, Kabul, Afghanistan www.cso.gov.af (accessed 29 April 2009).

Government of Afghanistan 2004a *Rural Water Supply and sanitation National Policy Framework*. Ministry of Rural Rehabilitation and Development, Kabul.

Government of Afghanistan 2004b *Household Survey in Health Facility Catchment Areas*. Ministry of Public Health of the Islamic Republic of Afghanistan, Johns Hopkins University, Kabul.

Gwatkin, D. R., Rustein, S., Johnson, K., Pande, R. P. & Wagstaff, A. 2000 *Socio-economic Differences in Health, Nutrition and Population in India*. NHP/Poverty Thematic Group, World Bank.

Hollis, S. & Campbell, F. 1999 What is meant by intention to treat analysis? Survey of published randomized controlled trials. *BMJ* **319**, 670–674.

Jensen, P. K., Ensink, J. H. J., Jayasinghe, G., Jayasinghe, G., van der Hoek, W., Cairncross, D. & Dalsgaard, A. 2002 Domestic transmission routes of pathogens: the problem of in-house contamination of drinking water during storage in developing countries. *Trop. Med. Int. Health* **7**(7), 604–609.

Klijn, F. 2002 Water supply and water collection patterns in rural Afghanistan: an anthropological study. DACAAR, Kabul, http://www.reliefweb.int/library/documents/2002/dacaar-afg-21jun.pdf (accessed 30 March 2010).

Knight, S. M., Toodayan, W., Caique, W. C., Kyi, W., Barnes, A. & Desmarchelier, P. 1992 Risk factors for the transmission of diarrhoea in children: a case-control study in rural Malaysia. *Int. J. Epidemiol.* **21**(4), 812–818.

Luby, S. P., Agboatwalla, M., Painter, J., Altaf, A., Billhimer, W. L. & Hoekstra, R. 2004 Effect of intensive handwashing promotion on childhood diarrhoea in high-risk communities in Pakistan. *J. Am. Med. Assoc.* **291**(21), 2547–2554.

Macy, J. & Quick, R. 2002 World spotlight: the safe water system. A household-based water quality intervention program for the developing world. *Water Conditioning and Purification*, www.wcponline.com/NewsView.cfm?ID=1478 (accessed 24 June 2009).

Mintz, E. D., Reiff, F. M. & Tauxe, R. V. 1995 Safe water treatment and storage in the home. *J. Am. Med. Assoc.* **273**, 948–953.

MOPH 2001 *MOPH Hygiene Education Policy Guidelines for Afghanistan*. Office of Water Quality, Sanitation and Hygiene Education, MOPH, Kabul.

Olembo, L. & Burnham, G. 2004 *Safe Water Systems: An Evaluation of the Zambia Clorin Program*. The Environmental Health project, Washington, DC, www.ehproject.org/PDF/Others/Zambia%20Report%20Format.pdf (accessed 3 February 2009).

PSI 2005 *Safe Water Systems–Clorin intervention*. Program approach information sheet, PSI, Kabul.

Quick, R. E., Venczel, L. V., Mintz, E. D., Soleto, L., Gironaz, M., Hutwanger, L., Greene, K., Bopp, C., Maloney, K., Chavez, P., Sobsey, M. & Tauxe, R. V. 1999 Diarrhoea prevention in Bolivia through point-of-use water treatment and safe storage: a promising new strategy. *Epidemiol. Infect.* **122**, 83–90.

Quick, R. E., Venczel, L. V., Gonzalez, O., Highsmith, A. K., Espada, A., Damiani, E., Bean, N. H., De Hannover, E. H. & Tauxe, R. V. 2006 Narrow-mouthed water storage vessels and in situ chlorination in a Bolivian community: a simple method to improve drinking water quality. *Am. J. Trop. Med. Hyg.* **54**(5), 511–516.

Roberts, L., Chartier, Y., Chartier, O., Malenga, G., Toole, M. & Rodka, H. 2001 Keeping clean water clean in a Malawi refugee camp: a randomized intervention trial. *Bull. World Health Organ.* **79**(4), 280–287.

UNDP 2004 *Afghanistan National Human Development Report 2004: Security with a Human Face*. UNDP, Kabul, http://hdr.undp.org/en/reports/nationalreports/asiathepacific/afghanistan/name,3292,en.html (accessed 30 March 2010).

UNDP 2006 Human Development Report 2006 Beyond scarcity: Power, poverty and the global water crisis. http://hdr.undp.org/hdr2006/pdfs/report/HDR06-complete.pdf (accessed 5 March 2009).

UNICEF 2006a *Best Estimates for Social Indicators for Children in Afghanistan 1990–2005*. Islamic Republic of Afghanistan, Kabul.

UNICEF 2006b *Progress for Children: A Report Card on Water and Sanitation*. www.unicef.org/wes/files/Progress_for_Children_No._5_-_English.pdf (accessed 6 August 2009).

UNICEF 2009 *State of the World's Children 2009*. UNICEF, Geneva.

Vyas, S. & Kumaranayake, L. 2006 Constructing socio-economic status indices: how to use principal components analysis. *Health Policy Plann.* **21**(6), 459–468.

WHO 2002 Managing water in the home: accelerated health gains from improved water supply. WHO, Geneva. Available from www.who.int/water_sanitation_health/dwq/wsh0207/en/ (accessed 20 March 2009).

Wright, J., Gundry, S. & Conroy, R. 2004 Household drinking water in developing countries: a systematic review of microbiological contamination between source and point-of-use. *Trop. Med. Int. Health* **9**(1), 106–117.