Development and implementation of water safety plans for small water supplies in Bangladesh: benefits and lessons learned

S. G. Mahmud, Sk. Abu Jafar Shamsuddin, M. Feroze Ahmed, Annette Davison, Dan Deere and Guy Howard

ABSTRACT

Water safety plans (WSPs) are promoted by the WHO as the most effective means of securing drinking water safety. To date most experience with WSPs has been within utility supplies, primarily in developed countries. There has been little documented experience of applying WSPs to small community-managed systems, particularly in developing countries. This paper presents a case study from Bangladesh describing how WSPs can be developed and implemented for small systems. Model WSPs were developed through consultation with key water sector practitioners in the country. Simplified tools were developed to translate the formal WSPs into a format that was meaningful and accessible for communities to use. A series of pilot projects were implemented by Non-Governmental Organisations (NGOs) across the country covering all major water supplies. The results show that WSPs can be developed and implemented for small community managed water supplies and improve the sanitary condition and water quality of water sources. Hygiene behaviour improved and household water quality showed a significant reduction in contamination. Chlorination was found to be important for some technologies, thus increasing the costs of water supply and raising important problems with respect to transfer to the communities. Simple tools for community monitoring were found to be effective in supporting better water safety management.

Key words | arsenic, Bangladesh, community water supply, water safety plans

S. G. Mahmud
Sk. Abu Jafar Shamsuddin
M. Feroze Ahmed
ITN Centre, 3rd Floor, Civil Engineering Department,
Bangladesh University of Technology,
Dhaka 1000,
Bangladesh

Annette Davison
Dan Deere
Water Futures,
32 Sirius Street, Dundas Valley, NSW 2177,
Australia

Guy Howard (corresponding author)
Department for International Development,
Abercrombie House, Eaglesham Road
East Kilbride, G76 8TB,
UK
Tel.:+44 1355 84 3718
Fax: +44 1355 84 3796
E-mail: *g-howard@dfid.gov.uk*

INTRODUCTION

In the third edition of the World Health Organization Guidelines for Drinking-Water Quality (GDWQ), the use of water safety plans is promoted as being the most effective approach to securing water quality (WHO 2004). Water safety plans are systematic approaches to water safety management covering all stages of water supply production and distribution from catchment to consumer (WHO 2004; Davison *et al.* 2005). A water safety plan emphasizes effective process control in water supply as the principal means of ensuring water safety. Water quality analysis is mainly used for periodic verification of water safety.

The experience with WSPs to date has primarily been within utility supplies; particularly those in developed countries. A variety of experiences have been documented (Deere *et al.* 2001; Davison *et al.* 2005, 2006; Yokoi *et al.* 2006). There have also been some initiatives applying WSPs to utility supplies in developing countries and experience is

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emerging (Howard *et al.* 2005). To date, however, there is limited documented experience with respect to small systems in either developed or developing countries, despite sustained interest and their importance as a means of water supply globally.

In countries where WSPs for small, community-managed water supplies are being developed, the focus has tended to be on the development of guided plans or model WSPs (Davison *et al.* 2005). This has been because of the difficulty in implementing water quality management in situations with limited technical expertise which are often remote. The use of model or guided WSPs may also help to significantly reduce the costs and complexity of implementing WSPs within utility supplies in developing countries (Howard *et al.* 2005).

The Ministry of Health in New Zealand has developed public health risk management plans (PRHMPs) for small systems, which effectively equate to a WSP. Most of these are termed 'guided plans' which take the user through the steps required for setting up a PHRMP. PHRMPs are increasingly being widely applied and the initial experience appears to be positive (Michael Taylor 2005, personal communication). Australia has been developing an electronic tool to support the development and implementation of WSPs for small systems (NHMRC 2005) but there remains limited information regarding the extent to which these have been applied. Iceland and Switzerland also have Hazard Analysis and Critical Control Point (HACCP) plans for smaller systems and again the experience has been positive (SWGIA 2003).

The WHO (1997) notes that the common element of community managed water supplies in developed and developing countries is the type of management, and in particular the use of untrained and often unremunerated community members to operate and maintain the water supply. Beyond this, however, there are great differences between the community managed water supplies in developed and developing countries.

The first and most obvious difference is the sheer number of community-managed water supplies in developing countries. The vast majority of rural water supplies in developing countries are community-managed and typically represent a much greater proportion of the overall water supply provision in a developing country compared to the much smaller numbers of such supplies in developed countries.

Furthermore, the technologies used in developing countries are typically much simpler than those used in developed countries. Many community managed water supplies in developing countries are not piped, but are point sources from which water must be transported in containers back to homes. Where piped supplies are provided, treatment is rarely used. Terminal disinfection for piped supplies is infrequently practiced and is usually only deployed at times of increased risk because of seasonal impacts or natural disasters.

Communities in developing countries often have very limited access to skilled technicians able to operate the supply. Furthermore, there is limited development of surveillance networks and communities have little access to professional support (WHO 1997; Bartram 1999). At the same time, however, it is in exactly these environments that the potential public health gains from improved water safety are likely to be the greatest and where WSPs can have the potential to improve community and personal health. For instance, Godfrey *et al.* (2006) noted that for small community supplies in Mozambique, water quality (which was generally relatively poor) would be best managed through a WSP approach.

Howard (2003*a*) described how WSPs offered a means of developing effective monitoring and control of water safety in small water supply systems in developing countries and presented examples of WSPs for a variety of technologies. This was further built upon by Davison *et al.* (2005) where a set of suggested 'model' WSPs for the most commonly used water supply technologies deployed in developing countries was given. Although useful, the material was largely technical and did not present the experience of its use and, consequently, there remains a paucity of documented experience of applying WSPs to small systems in developing countries.

In this paper, a case study on the development and implementation of WSPs for small community-managed water supplies in Bangladesh is presented. The material presented should help other developing countries in applying and evaluating WSPs.

Location description

Bangladesh is a low-income country, but economic growth over recent years has been sustained and significant. Many development indicators are poor, for instance 36,000 children under 5 are estimated to die every year from diarrhoea (Rahman *et al.* 2005).

Bangladesh made enormous strides in the 1980s and 1990s in providing improved water supply to its rural population through the use of shallow tubewells fitted with a handpump, primarily through households purchasing equipment direct from suppliers. In the Global Water Supply and Sanitation Assessment Report 2000, it was estimated that 97% of the rural population had access to an improved water supply within 30 minutes collection time of their dwelling (WHO & UNICEF 2000).

In 1993, arsenic was detected in shallow tubewells in the Chapai Nawabganj district in north-western Bangladesh and since that time, the scale and severity of the arsenic problem has been better described. Based on a national survey, BGS & DPHE (2001) estimated that 27% of all tubewells were likely to be contaminated with arsenic above the Bangladesh standard of 50 μg/l and 46% above the provisional WHO Guideline Value of 10 μg/l. Subsequent blanket screening of the affected sub-Districts suggests that the proportion of tubewells contaminated above the Bangladesh standard is about 20%, putting some 20–25 million people at risk from arsenic (NAMIC 2004). Arsenic contamination meant that rural coverage was estimated to have dropped to 72% in 2002, and Bangladesh was considered to be off-track to meet water Millennium Development Goal target 10 (WHO & UNICEF 2004).

The Government of Bangladesh prioritises the use of alternative water supplies for arsenic mitigation (GOB 2004). To date, 107,000 alternative water supplies have been installed (APSU 2005). The introduction of new water supplies, however, raises the potential for risk substitution where new hazards are introduced into a water supply (Howard 2003*a*; Howard *et al.* 2006). During a risk assessment of mitigation options, significant risk substitution was identified among many options and it was concluded that the introduction of WSPs was essential to support communities in managing the safety of their water supplies more effectively (Ahmed *et al.* 2005; Howard *et al.* 2007).

METHODS

Development of WSPs

The first stage in the process of developing WSPs was a national conference held in Dhaka in July 2004 when the third edition of the WHO Guidelines for Drinking-Water Quality (WHO 2004) were presented and the importance of WSPs in securing safe drinking water was discussed. This approach resulted in a firm commitment from all stakeholders to implement WSPs in rural water supplies in Bangladesh.

The second stage was to develop draft WSPs that could be tested in the field. This stage was done through a workshop held at the ITN Centre in the Bangladesh University of Engineering and Technology in November 2004, for key sector professionals. The workshop was tasked with developing WSPs for the following key technologies:

1. Protected dug wells;
2. Pond sand filters;
3. Rainwater harvesting;
4. Deep tubewells;
5. Small piped water systems from a tubewell source,
6. Small piped water systems from a surface water source with subsequent multi-stage filtration;
7. Small gravity piped system from a spring source; and
8. Shallow tubewells

The participants were formed into small working groups and each group was given a set of blank *proformas* which were adapted from examples used in previous exercises in Australia (Water Futures 2004) and elsewhere including workshops held on behalf of the WHO in Seattle, USA, 2003 (Stevens *et al.* 2002). The blank *proformas* led the groups through each stage of formulating the WSP in a coherent format. This followed a slightly modified approach from that outlined in Davison *et al.* (2005) and WHO (2004) and is shown Figure 1.

For each technology, a systematic analysis of likely hazards that could affect the water supply was undertaken. A hazard event analysis was then carried out to see how the hazards identified could enter the water supply and a semi-quantitative risk assessment was undertaken. For each risk,

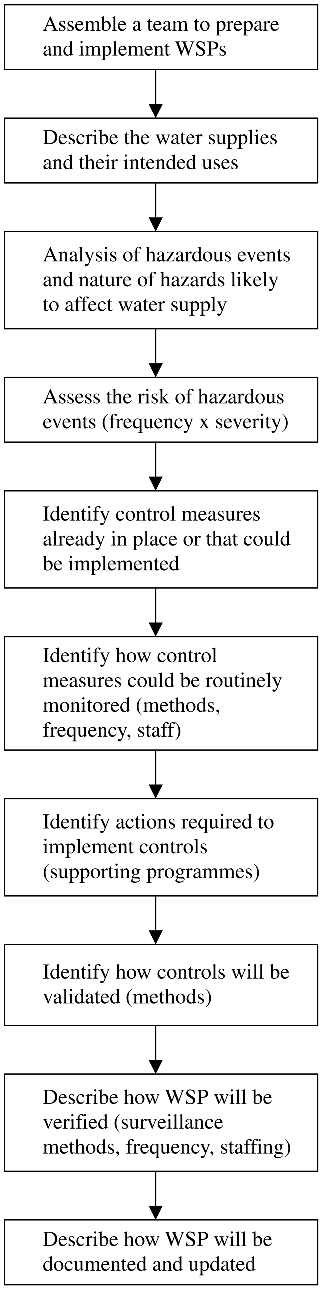

Figure 1 | Process for developing water safety plans used in Bangladesh.

appropriate control measures and how these could be monitored were identified. An action plan was then drawn up to define which actions were required to improve the water supplies. Finally, the means of validating the control measures and plans for verification were prepared. This information was then consolidated into a set of formal documents with the professionals involved in preparing these, listed at the start of each document. An extract of one WSP is shown in Figure 2.

Development of community monitoring tools

In order to be able to transfer the formal WSPs into a format which was accessible to the communities who would implement the WSPs, a set of simplified pictorial tools was developed for caretakers and other community members. These tools were designed to assist the community in assessing the hazardous events which could affect their water supply; the actions required to promote effective water safety management; how control measures could be simply monitored and the corrective actions to be taken.

Pilot projects

Following the development of the WSPs, pilot projects, supported by the Arsenic Policy Support Unit (APSU), were undertaken between February and November 2005 by 3 NGOs: Dhaka Community Hospital (DCH), Environment and Population Research Centre (EPRC) and NGO Forum for Drinking Water Supply and Sanitation. In 2006, APSU also provided support to a Government of Bangladesh project (BAMWSP) to implement WSPs for rural supplies and to provide technical support to the development of a WSP for one urban supply. UNICEF also implemented WSP pilots in 19 Upazilas during 2005. This paper reports the experiences gained from the three NGO pilots as these were the best documented.

Each of the NGOs supported by APSU undertook work in selected communities to trial the effectiveness of the WSPs, to assess the impact of the WSPs and to review the effectiveness and acceptability of the tools developed for use by communities over a 10 month period. The 82 communities covered were spread across Bangladesh and covered all technologies except gravity-fed piped water schemes. The latter represent a very minor proportion of rural water supplies in Bangladesh and are primarily restricted to the Chittagong Hill Tracts in the extreme east of the country.

The NGO Forum covered 196 water supplies in 38 villages spread across all 5 Divisions of Bangladesh and covering all major water supply technologies except gravity-fed piped supplies. DCH included 21 villages in the four

Process Step	Hazardous Event	Hazard Type	Control Measures Current and/or Planned	Risk	Basis	Action Required to Help Reduce Risk?	
						✓/✗	What?
TW1 Catchment around source	Leaching from over-application of fertilisers or organic waste dumps	Nitrate and nitrite	Fertilisers not used within at least 10m of the well Waste dumps located at least 10m from the well	U (STW) I (DTW)	Public health risk from raised nitrate and nitrite	✓	Community discussion to agree minimum distance for fertiliser use and waste dumps
	Faecal contamination through sub-surface leaching from human or animal waste	Microbial (B,V) Nitrate	Prevent open defecation by community Ensure pit latrines located acceptable distance (if no specific guidance then use 10m from well as a default) Prevent animal yard/pen within 10m of well Provide fence around tubewell	S (STW) U (DTW)	Public health risk from pathogens from human and animal faeces	✓	Promote sanitation within the community. Establish minimum safe distance for latrines and animals pens (check with DPHE or NGO) and agree with community to keep faecal material away from the well. Ensure fence does not prevent access for some members of community.
TW2 Groundwater used for tubewell	Presence of natural chemicals in tubewell	Arsenic Manganese Boron Iron Others	Ensure all water sources tested prior to commissioning Use a test borehole to expected depth before digging well	S	Public health risk from raised arsenic and other chemicals and rejection of water due to staining from manganese or iron	✓	Ensure tests performed before commissioning
TW3 Tubewell	Ingress of contaminated water through cracks and mouse burrows undercutting the platform	Microbial (B,V,P)	Platform is of sufficient size and properly maintained to prevent flow-paths developing; fence surrounds tubewell	S	Public health risk from pathogens from human and animal faeces	✓	Ensure correct mortar mix used and make repairs when required
	Ingress of contaminated water through poorly sealed rising main	Microbial (B,V,P)	Ensure top 5m of annulus properly sealed	S	Public health risk from pathogens from human and animal faeces	✓	Monitor construction quality and materials specification
	Entry of contaminated stagnant water due to poor drainage	Microbial (B,V)	Spilt water is properly drained away from the tubewell platform	S	Public health risk from pathogens from human and animal faeces	✓	Ensure apron properly constructed and repair cracks. Dig drains around well and keep clean. Motivation for sanitation improvement in community.
	Ingress of contaminated surface water during flooding	Microbial (B,V,P)	Ensure the tubewell is raised above the flood level	S	Public health risk from pathogens from human and animal faeces	✓	Raise tubewells above flood level Provide drainage around tubewells
TW4 Handpump	Contamination introduced through use of contaminated priming water for handpump	Microbial (B,V,P)	Ensure pump foot valve in good condition Ensure only clean water is used to prime handpump	S	Public health risk from pathogens from human and animal faeces	✓	Install new seat valves

NB: B = bacteria; P = protozoa; V = virus; STW – shallow tubewells; DTW = deep tubewells

Figure 2 | Extract of WSP for deep tubewell (ITN-BUET 2006).

Upazilas (sub-Districts) of Serajdikhan (Munshigonj District) and Pabna (Pabna District) and included dug wells, rainwater harvesters and pond sand filters. EPRC covered 23 villages in Kallia Upazila in Narail District and included deep and shallow tubewells, pond sand filters, dug wells, rainwater harvesters and piped water from deep tubewells. EPRC also included chlorination as an additional part of the WSP in some of the dug wells and pond sand filters in line with the recommendations of Ahmed *et al.* (2005). This also allowed EPRC to assess whether chlorination should be included as a standard part of the WSPs.

Each organisation formed a core team at their national headquarters and conducted training and orientation. The organisations then formed local WSP teams among their field staff and local NGOs who worked with them in partnership.

In each pilot, baseline assessments of water quality, sanitary condition and hygiene practices were undertaken. A small sub-set of water supplies in each pilot were also included in intermediate assessments to evaluate progress and final assessments to try to quantify improvements in the water supply as a result of implementing the WSPs.

Sanitary inspections were undertaken using standardised formats based on Howard (2003a, b) and WHO (1997). The inspection forms for different technologies had differing numbers of questions, so the risk scores were converted into percentages to allow comparison. The sanitary risks were then classified into three broad categories of sanitary risk: low (0–30%), medium (31–70%) and high (above 70%). Water quality analysis included thermotolerant coliforms (TTC) and a set of key chemical parameters (arsenic, manganese, nitrate and iron). In all cases, most analysis was carried out in the laboratory except in Sylhet Division where the NGO Forum used a portable field test kit as it was not possible to ensure the samples would be brought to their laboratory in time to prevent deterioration in water quality. Household water as well as source water was included in these assessments.

Hygiene awareness and behaviour was assessed through knowledge, attitude and practice (KAP) surveys. In addition, the NGO Forum collected data on the incidence of diarrhoea in the previous 2 weeks for the baseline and final assessments.

Community training

Caretakers received a one-day training programme on operational monitoring, repair and preventive maintenance of water options. This training acted largely as a refresher to previous training on operation and maintenance. At the training programme, the WSP tools for monitoring the water supply were explained and distributed to the caretakers. In addition, hygiene sessions were provided to water point management committees, caretakers and communities to ensure that awareness of the WSP supported improvements was present throughout the water chain.

In the NGO Forum pilot, the caretakers were asked to monitor the water points every 15 days using the pictorial tools. Caretakers were provided with a notebook and pen to note down the information about their periodic monitoring and asked to keep records in their notebook in Bangla. In the case where the caretakers were not literate, they were helped by their children or neighbours. Likewise in the EPRC pilot, a record-keeping chart was attached to the APSU community monitoring tool to keep a record of actions, DCH did not implement any formal process of recording actions taken.

RESULTS

Community tools

There were no quantitative data collected on the use of the tools, although, improvements in sanitary conditions indicate a positive response. The feedback obtained by NGO Forum through discussion with the caretakers about the WSP pictorial tool indicated that the caretakers found them easy to understand. Caretakers considered the tools to play a vital role in guiding and monitoring corrective actions and to help them to support better the accountability between the caretakers and committee.

DCH discussed the tools with the caretakers and village committees to get their perceptions. The tools were found to be user friendly and effective. The WSP tool was well received by the caretakers and was considered to be important in assisting them in monitoring and taking corrective actions for the water supply options. In all pilot projects, committees were asked to use the monitoring tools and the WSP approach as a means of monitoring the performance of the caretakers. The feedback that was received showed that this worked reasonably well and committees became more engaged in monitoring and managing water safety than previously had been the case.

There were a number of examples where the use of WSPs led to direct action by caretakers which would improve the safety of the drinking water. These actions included repairs to damaged water source infrastructure, moving sources of contaminants such as latrines and animal pens, and cleaning the surroundings of the water supplies. This information lends support to the accessibility and usefulness of these tools.

Both NGO Forum and EPRC found that caretakers were reluctant to keep written records. This was reflected in a random survey where about 58% of the caretakers did not complete the record-keeping chart.

Sanitary risks and water quality

The experiences from all three NGO projects showed that the sanitary conditions of the water supplies improved significantly, as shown in Table 1. All three projects found a significant increase in the proportion of supplies classified as low risk and that communities were willing to undertake key actions, such as moving pit latrines, despite the difficulties that these sometimes entailed. Both the NGO Forum (for pond sand filters) and DCH (for rainwater harvesters) found small increases in overall sanitary risks, suggesting that in these cases the WSP training has been less effective.

Dug wells in each project showed marked improvements, and this was particularly so in the DCH pilot at Pabna, where the dug wells were initially in the high risk category. As a result of these findings, rehabilitation work was undertaken on the water supplies as part of the WSP which resulted in all dug wells at this site moving into the low risk category.

There were some reductions in microbial contamination as measured by TTC. Both EPRC and DCH compared their water quality to the scale proposed in the protocol for drinking water surveillance by DPHE (DPHE 2005), shown in Table 2. This scale draws on work by Lloyd and Bartram and the results of a risk assessment tool developed by Ahmed *et al.* (2005).

For the analysis of the pilot projects, data in the very low and low risk categories were combined, as were the data in the high and very high categories, given the small numbers of supplies in the very low and very high risk categories. The EPRC pilot project found that the proportion of water supplies in the high to very high risk category reduced by 20% for the water supplies included in their first phase and by 30% of water supplies included in their second phase of the project.

The pilots showed a significant improvement in microbial quality for individual technologies. The EPRC pilot showed that for dug wells the proportion of samples in the ‘no’ to ‘low risk’ category was increased by 40% during the period of the pilot and the proportion of samples in the high to very high risk categories decreased by 20% (Figure 3). It was noted, however, that the quality of dug well water deteriorated between the intermediate and final surveys, which was attributed to heavy rainfall just before

Table 1 | Distribution of sanitary risks by category

	Baseline surveys (percent)			Final surveys (percent)		
Pilot project	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**
DCH	70	6	24	100	0	0
EPRC	63	26	10	93	6	1
NGO Forum	71	24	5	86	14	0
Total	69	22	8	89	11	1

Table 2 | Grading of water quality based on thermotolerant coliforms in water related to potential maximum disease burden (DPHE 2005)

Count per 100 ml	Category	Remarks
0	A	Very low risk, water safety is verified. It is unlikely that water will cause any significant disease in the community
1–10	B	Low risk, water safety can be considered as being conditionally verified in non-chlorinated supply, but attempts should be made to improve quality. Water is likely to contribute to infectious disease, but will be a minor contributor compared to other routes
10–100	C	Intermediate risk, water cannot be considered as safe. Water is likely to be a significant contributor to disease and at upper levels is significantly in excess of the WHO reference level of risk
100–1000	D	High risk, water is unsafe. At higher levels of contamination, water is likely to be a primary contributor of disease in the community and is very significantly in excess of the WHO reference level of risk
>1000	E	Very high risk, water is extremely hazardous. Water is likely to be the primary source of infectious disease in the community and is very significantly in excess of the WHO reference level of risk

the final survey. Reductions in the median TTC count was noted for all dug wells in the EPRC pilot projects. The inclusion of chlorination of dug wells led to greater reductions in TTC counts (from 200 cfu/100 ml to <1 cfu/100 ml) than when WSPs were implemented without chlorination (100 to 40 cfu/100 ml).

EPRC also found improvements in water quality in pond sand filters following the implementation of the WSPs (Figure 4). For supplies without chlorination, TTC counts reduced from 280 cfu/100 ml at baseline to 37 cfu/100 ml at the final survey. Where chlorination was applied, a reduction from 48 to 17 cfu/100 ml was noted. This shows that the actual final quality was better with chlorination, but that significant improvements in water quality resulted even without its use.

EPRC found that TTC levels in rainwater harvesters did not decline much during the WSP project, with only a slight increase of water supplies considered in the very to low water quality risk category (from 20 to 33.3%) mirrored by a similar decrease in supplies from the high to very high water quality risk category. Sanitary risks were also noted as being high.

In the DCH pilot, after implementation of the WSP pilot project, no dug wells showed microbial contamination. Pond sand filters in the final assessment still showed some contamination, but the numbers of TTC detected were very low. Rainwater harvesters were generally found to have low TTC counts.

In the NGO Forum pilot, the average microbial contamination was compared. The mean TTC count in source waters was 18 cfu/100 ml and 25 cfu/100 ml in the

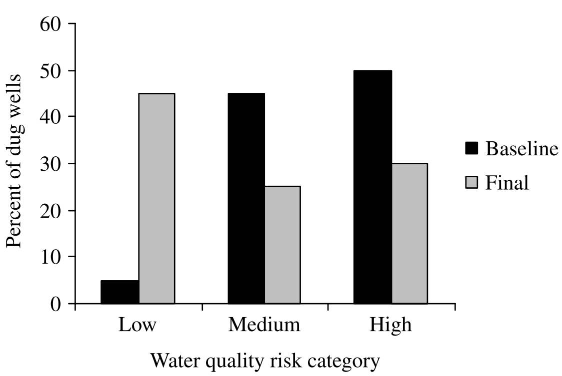

Figure 3 | Microbial quality of dug wells at baseline and final survey EPRC pilot project.

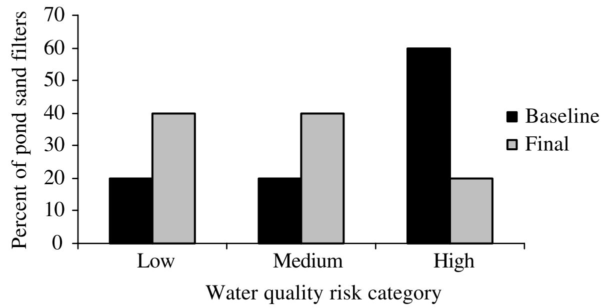

Figure 4 | Microbial quality of pond sand filters at baseline and final survey EPRC pilot project.

baseline surveys of the 1st and 2nd phases respectively. In the final assessment, the mean TTC count had reduced to 14 cfu/100 ml. Although NGO Forum found a reduction in average contamination, the reduction in water supplies with no TTC detected was only marginal. The technologies most likely to be contaminated were the rainwater harvesters, which also had higher sanitary inspection scores, and dug wells. However, all technologies showed at least some examples of contamination including both the deep and shallow tubewells and the pond sand filters.

Household water

The NGO Forum reported at the baseline survey that about 8% of the respondents were found to dip their hands during water collection to remove excess water from the container. After hygiene education under the WSP pilot project, only 2% of respondents were found to continue with this practice. During the baseline assessment it was found that about 74% of the respondents covered water containers during transportation, which rose to 95% in the final survey (Figure 5).

EPRC found that hygiene practices improved across all technologies (Table 3) with particular improvements noted for users of dug wells and pond sand filters as a result of hygiene education in the WSP pilot project.

The EPRC pilot found that hygiene education with respect to water handling practices resulted in improvement in the quality of water stored in the home. The proportion of samples in the DPHE protocol in the no to low risk category increased by 20% and the proportion in the high to very high risk categories reduced by 15% (Figure 6). However, the data suggest the need for ongoing hygiene promotion for effective results.

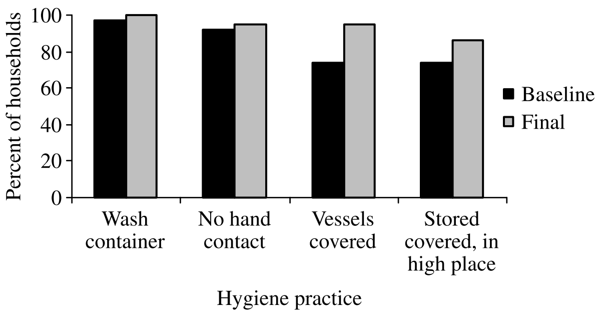

Figure 5 | Improvement of hygiene practice NGO Forum pilot project.

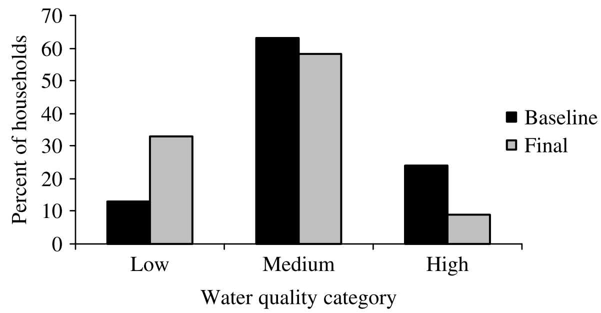

Figure 6 | Microbial quality of water stored in houses at baseline and final survey EPRC pilot project.

EPRC compared improvement in the quality of water stored in the home by source water technology, as shown in Table 4. Household water taken from pond sand filters showed the biggest decrease in contamination, with contamination reducing by almost two-thirds. Household water taken from dug wells showed a reduction in contamination, but by a much less significant degree, although at the intermediate assessment the contamination was only 8 cfu/100 ml, suggesting that bigger increases were possible. It is likely that the increase between intermediate and final assessment related to the large climatic depression which resulted in very heavy contamination.

NGO Forum found a 12% reduction in diarrhoea incidence in the previous 2 weeks between the baseline and final assessments of the WSP pilot project. This indicates a direct health benefit derived from improved water safety management at the source and within the homes of users.

Table 3 | Percent households following hygiene practices by selected technologies EPRC pilot project

	Dug wells		Pond sand filter		Rainwater harvesters	
Practice	**Baseline**	**Final**	**Baseline**	**Final**	**Baseline**	**Final**
Kept covered	65	93	75	83	87	93
Stored in clean and high place	39	72	37	100	47	67
Vessels covered	14	70	0	75	47	80
No hand contact	29	91	66	100	87	100
Wash container	30	90	53	100	80	93

The baseline assessment in the EPRC pilot found only 60% of dug wells met the Bangladesh standard for arsenic, 90% met the manganese standard, 88% met the iron standard and all dug wells met the nitrate standard. In the final assessment, EPRC obtained similar results but noted that iron concentrations had reduced in dug wells where chlorination was used and that arsenic in dug wells decreased during the wet season. The NGO Forum pilot only found problems with manganese at both baseline and final assessments, with 74% of tubewells having manganese in excess of the Bangladesh standard. DCH found excess iron and manganese in some dug wells, but overall chemical water quality met Bangladesh Standards.

DISCUSSION

The overall feedback from the WSP pilot projects was positive. The success of a diverse range of organisations in implementing WSPs provides some confidence that their

Table 4 | Median microbial water quality (cfu/100 ml) stored in the home by source type EPRC pilot project

Technology	**Baseline**	**Final**
Dug wells	90	65
Deep tubewells	–	–
Shallow tubewells	41	12
Pond sand filters	102	35
Rainwater harvesters	–	–

use can be scaled up, although the limited time of the pilot projects means that some care needs to be applied in evaluating their success. The WSPs themselves have been well accepted by the NGOs and other stakeholders as an effective guide for understanding how water safety can be consistently assured. A number of suggested improvements and changes have been identified for the ongoing process of revision of the WSPs. Updated versions of the WSPs were recently produced from a further expert review workshop (ITN-BUET 2006).

The pictorial tools for community monitoring encouraged the caretakers to undertake prompt preventative maintenance to ensure safety of water. It was also found that the caretakers can play an effective role in the motivational activities towards safe water handling by the community.

The pilot projects showed consistent reductions in sanitary risk, and improvements in microbial quality. These reductions and improvements are not uniform, however, and some caretakers performed better than others. This information indicates the need for periodic follow-up with communities through surveillance, which could also be used as an effective means of verifying the WSP.

WSPs were implemented for both new and existing water supplies. The design and construction phases of water supply provision should take into account risks of contamination and provide means of controlling the risks identified. The assessment in the DCH pilot project in Sirajdikhan showed that rehabilitation work during WSP pilots resulted in significant improvement in the water quality.

The water quality data show positive trends in reducing contamination. However, the data also show that it is difficult to achieve an absence of TTC for small community rural water supplies, which is a finding consistent with previous work (Lloyd & Bartram 1991; Howard *et al.* 2003). Most commentators note that it is more important to achieve an overall and sustained reduction in sanitary risks and microbial contamination, rather than aim for an absence of indicator bacteria (Lloyd & Bartram 1991; WHO 2004). The improvements in microbial water quality varied between the technologies, with tubewells (particularly deep tubewells) having the best microbial quality results. Rainwater harvesters showed a disappointing performance, perhaps because these are mainly household supplies and thus the training and support required is much more substantive.

In many cases, WSPs for dug wells and pond sand filters resulted in significant improvements on the ground, but chlorination is likely to be required at least seasonally and should be incorporated into the WSP and community monitoring processes. In the longer-term the need for chlorination will present challenges in ensuring that appropriate technologies can be developed and successfully transferred to communities, with a concomitant increase in the cost of the technologies.

In a number of settings, there has been successful introduction of household level chlorination in Bangladesh and other countries (Sobsey 2006) and significant reductions in diarrhoeal disease have been shown (Clasen *et al.* 2006). The EPRC project attempted the introduction of household chlorination, but found that sustained use was more limited than for source water chlorination. This would benefit from further research given the generally positive experience in other, similar, environments.

The WSPs prepared in Bangladesh relied on the source selection stage to resolve chemical water quality problems and chemical testing was used to verify source selection. The results indicate that for the dug wells in the EPRC pilot there were problems with arsenic in particular, but also to a lesser extent manganese and iron. The NGO Forum and DCH pilot projects found problems with manganese and iron in dug wells. This suggests that there needs to be improvements in source selection processes as part of the WSP process. In some cases new WSPs are required for technologies designed for chemical removal – for instance the arsenic and iron removal plants and arsenic removal technologies. The WSPs for these technologies must include simple operational parameters for monitoring which will have to be relevant to chemical quality.

Davison *et al.* (2005) note that an important component of a WSP is adequate and comprehensive documentation to show that action and management plans are in place for immediate reaction to detected problems. However, the apparent reluctance of caretakers to record monitoring activities raises questions as to how feasible this will be for community supplies. The experience from the WSP pilot projects in Bangladesh suggests that the records of community meetings and occasional surveillance visits are an appropriate way to address these issues.

A number of improvements were noted as being required for the community monitoring tools to reflect different designs and to improve comprehensibility. The use of some written components on the tools was suggested and this may assist the process, but the value of this is likely to vary depending on the particular communities, as literacy is variable. The experience from the pilot projects indicates that developing standard tools for use by all agencies working with communities is not realistic, in part because designs of technologies vary. It may be more effective for different programmes and projects to adapt the tools to meet local conditions and for guidance to concentrate on ensuring that the key message is included. Thus whilst a model WSP is retained, the tools for communities to implement these may vary significantly.

Some concern was raised during the pilot projects that despite communities appreciating the value of the monitoring tools, some caretakers undertook the monitoring and corrective actions irregularly. Further work will be needed to find the most appropriate ways of transferring these tools and WSP concepts to caretakers to ensure effective implementation.

In these pilot projects, it was found that the existing committees can play important roles in the implementation of WSPs through supervising and cross-checking caretakers' activities. The NGOs suggested that the involvement of these committees can be vital in ensuring that caretakers continue to follow best practice. Other work in Bangladesh, however, points to the limited impact of committees on ensuring that water supplies installed for arsenic mitigation remain functional (Kabir & Howard 2007). The value and role played by committees in WSPs and arsenic mitigation remains somewhat debatable. What is clear is that a functioning surveillance system will be important to promote effective uptake of WSPs and the pilot projects all demonstrated the usefulness of follow-up and surveillance. This will be a major challenge for Bangladesh given the number of water supplies that would have to be covered.

The ongoing sanitation and hygiene campaigns across Bangladesh should make promotion of WSPs easier. It will be important for projects and programmes implementing WSPs to integrate their training with hygiene promotion, caretaker training and awareness-raising. The use of existing processes and approaches will be more cost-effective and are likely to be more sustainable than stand-alone activities.

All major water supply projects in Bangladesh have committed to implementing WSPs in their projects and WSPs have been identified in major sector documents as being required. What is emerging is a process of regular interaction, with the establishment of a forum of organisations undertaking WSPs, sharing information and working together to update the WSPs. The WSPs are now in their second edition and can be accessed from the ITN website (www.buet.ac.bd/itn). Further development of WSPs for new systems like Arsenic Removal technologies is underway.

There are some key challenges for scaling up WSPs. The biggest challenge is the scale of activity required, given that there are between 7.5 and 10 million shallow tubewells in the country, most of which are owned by households. The rolling out of WSPs will have to consider how this scale of activity will be achieved. It is likely that in the first instance, the most appropriate approach will be to focus on community water supplies. A strategy is required for rolling out the information and training on WSPs for household rainwater harvesters and safe shallow tubewells.

For some of the actions required to improve water safety, such as relocation of latrines, there are serious space constraints. Furthermore, at present there is no widely accepted information on minimum safe distances of latrines to water supply sources in Bangladesh. Further work is required to define minimum safe distances and where these cannot be assured, to define other interventions which could improve water safety.

The WSP pilots have benefited from expert input from a number of national and international resources. It will be important for future scaling up that the pool of expertise is increased and that a group of experts able to guide and provide technical assistance is developed, particularly at the local level.

CONCLUSION

The results of the piloting in Bangladesh show that WSPs can be implemented for community-managed water supplies in developing countries. The results point to significant and consistent reductions in sanitary risks and improvements in microbial quality. The use of simple monitoring tools for the community to use was highlighted as particularly important, as was the need for ongoing surveillance. The fact that all major water projects in Bangladesh now plan to implement WSPs is an indication of the acceptability of the approach and it is expected that the WSPs will go through ongoing improvements and modifications. Fundamental to the ongoing success of WSP development and implementation, however, will be sustained surveillance and further capacity building in WSPs at the local and regional level.

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