Multiple-use water supply systems: do the claims stack up? Evidence from Bangladesh

MAARTEN FONTEIN, JAMES WEBSTER and PAUL TRAWICK

This paper reports on an investigation of a multiple-use water supply system (MUS) in Bangladesh which set out to test the claim that MUS meet users' needs for water more effectively than single-use systems. A water needs framework was developed and water users (84) from three villages were interviewed during June–July 2007. The opinion of the users was that the MUS meet their needs for water better than the conventional systems they replace. The benefits include increased productivity and incomes, reduced irrigation costs and easier access to iron-free domestic water. However, the systems are not affordable for the communities over a ten-year timeframe. The poor have less access to the piped household supply contrasting to near universal access to hand tubewells. Problems are identified relating to ownership, management, representation, skilled staff, external support and the legal framework that leave users vulnerable to powerful owners who control water supply.

Keywords: Bangladesh, multiple-use, water supply, water needs.

> The proponents of MUS claim increased potential to reduce poverty and improve health

In recent years the profile of multiple-use water supply systems (MUS) as a means of improving water supply in developing countries has significantly increased (e.g. Smits et al., 2004; IWMI, 2006; van Koppen et al., 2006). The proponents of these systems claim increased potential to reduce poverty and improve health over and above conventional single-use systems (Smits et al., 2004). They argue that these benefits arise because the productive uses of water are catered for thereby enhancing the livelihoods of the poor, increasing incomes and reducing vulnerability. Higher incomes lead to improved nutrition and provide the means to take preventive health measures and pay for health care (IWMI, 2006). Furthermore, these benefits are 'mutually reinforcing' as improved health and nutrition have a positive effect on productivity (van Koppen et al., 2006: 10). Cost recovery, vital for sustainability (WASH, 1994; Carter et al., 1999), is also improved because higher incomes increase both the ability and the willingness of the poor to

Maarten Fontein (maarten.fontein@googlemail.com) has been working in humanitarian aid with Medair; James Webster is a lecturer in Community Water Supply at Cranfield University and Paul Trawick is a Senior Lecturer in Environmental Anthropology at Cranfield University. *The authors gratefully acknowledge the funding of this research by the Jack Wright Memorial Trust and UK Irrigation Association, and the assistance provided by Mr M.A. Matin, Director, Rural Development Academy, Bangladesh.*

doi: 10.3362/1756-3488.2010.005, ISSN: 0262-8104 (print) 1756-3488 (online)

pay for water (Kayaga et al., 2003; IWMI, 2006). Equally important for sustainability is a sense of ownership (Narayan, 1995; Carter et al., 1999) and it is claimed that MUS inherently engender this because the involvement of communities in the design of the systems is central to the MUS approach (IWMI, 2006; van Koppen et al., 2006). Claims are also made of improved gender equity as the systems are designed to meet the needs of women (IWMI, 2006).

In practice, water supplied by single-use systems is almost universally used for multiple purposes (van Koppen et al., 2006). A range of systems exists from those designed and used for a single purpose to those that are fully multiple-use in design and operation, as shown below:

- *De facto multiple-use systems*. Systems designed for a single purpose, but which users put to multiple-uses.
- *Domestic-plus and productive-plus*. Designed 'add-ons' to either domestic or productive schemes that fall short of fully providing for multiple needs.
- *Multiple-use by design*. Based on a full participatory assessment of needs and resources (human and water), and specifically aimed at making the most effective use of the latter to meet the former in an equitable and poverty focused manner (Smits et al., 2004; van Koppen et al., 2006).

Are systems designed for multiple uses better able to meet people's needs than those designed for single use?

The central claim put forward for MUS is that as humankind's requirements and uses for water are multiple, integrated systems designed to supply water for multiple uses are inherently better able to meet people's needs for water than systems designed for single use (e.g. Smits et al., 2004; IWMI, 2006; van Koppen et al., 2006), leading to the benefits outlined above. This paper reports on an investigation of a MUS in Bangladesh that sought to test this assertion.

Bangladesh and the MUS model

The MUS model investigated was developed by the Rural Development Academy (RDA), an organization that seeks to implement Government of Bangladesh (GoB) policy through research, action research, training and consultancy in rural development. The RDA model is 'multiple-use by design' and features a deep tubewell (DTW) which supplies a ground-level irrigation tank from where water is distributed to agricultural land via concrete pipelines or to an overhead tank for domestic water supply. Domestic water is distributed to household taps via a PVC pipe network and there is the option of installing arsenic (As) and iron (Fe) removal plant where necessary. Low-cost DTW technologies are employed, including manual drilling

The owners' groups recover capital costs, pay for operating expenses and take a marginal profit

techniques and local materials and components. The formation of owners' groups is an essential part of the model and these are required to invest 10 per cent of the capital costs as a down payment and repay the entire capital costs over ten years. The owners' groups recover capital costs, pay for operating expenses and take a marginal profit by charging the users for water. They have autonomy in setting tariffs. Staff and management training is provided by the RDA.

There are a plethora of terms and definitions relating to tubewells, such as shallow tubewell (STW), deep-set shallow tubewell (DSSTW), force mode tubewell (FMTW) and so on. In this paper the following terms with their respective definitions will be referred to:

- *Hand tubewell (HTW)*. A tubewell with a handpump used primarily for domestic water.
- *Shallow tubewell (STW)*. A tubewell used for irrigation with a low-lift diesel pump (LLDP).
- *Deep tubewell (DTW)*. A large bore (≥ 200 mm) tubewell with a submersible pump.

The predominant irrigation systems that the RDA MUS model replaces are LLDPs abstracting water from rivers and STWs for distribution to cropped areas via open channels. In Bangladesh irrigation has an important role in improving agricultural productivity but a recent report has described irrigation performance as poor (IWMI, 2004). The problems cited include high seepage losses, inadequate power supplies, and little community participation in the design, implementation and management of irrigation projects. Water management groups and associations were found to be ineffective.

For most of the population drinking water comes from hand tubewells

For between 80 and 85 per cent of the population (Hoque et al., 2006; Hossain et al., 2006), drinking water comes from HTWs. In 1993 natural As contamination of groundwater was discovered which is now known to extend over 270 of Bangladesh's 464 *upazillas* (APSU, 2006). An estimated 35 million people are exposed to arsenic concentrations above 0.05 mg/l from nearly 3 million contaminated HTWs (Ahmad et al., 2004; APSU, 2006). In Bangladesh, HTWs are widely considered to be a microbiologically safe source of domestic water, although faecal contamination of tubewells has been demonstrated (Macdonald et al., 1999; Hoque et al., 2006).

56 per cent of rural households are 'functionally landless'

Despite 2.5 per cent annual increases in GDP between 1990 and 2004 (UNDP, 2006), poverty maintains its grip on Bangladesh, which is ranked 85th of 103 countries in the Human Poverty Index (ibid.). Much of this poverty is related to land distribution; 56 per cent of rural households are 'functionally landless' (owning <0.2 ha) (Ali, 2007). Reflecting this, 53 per cent of the rural population are below the poverty line (IWMI, 2004). Associated with poverty, the Bangladesh health statistics – infant mortality of 56/1000 live births and life expectancy of 62.6 years – leave much to be desired and gender inequality prevails (UNDP, 2006).

With such a profile, the claims made for MUS – increased potential to reduce poverty, improve health, enhance cost recovery and a sense of ownership leading to improved sustainability, and increase gender equity – do promote MUS as an attractive option for achieving the Millennium Development Goals in Bangladesh (van Koppen et al., 2006). However, for these benefits to be realized, the MUS implemented must meet people's needs for water better than the conventional systems they replace. The purpose of the study reported here was to determine whether the RDA MUS can achieve this.

'Water needs'

Each water use has particular requirements for quality, quantity, location and timing of use

'Water needs' involve the purposes for which people use water, for example, washing clothes, irrigating crops and so on, and these can be divided into 'domestic' and 'productive'. Each use has particular requirements for quality, quantity, location and timing of use. The concept of water needs also involves the supply system that provides the water. Certain elements have to be in place for water of the required quality and quantity to be provided at the appropriate location and time. These system requirements include hardware aspects, such as equipment resilience, software considerations, such as community ownership, and institutional elements, such as back-stopping agencies (WASH, 1994; Narayan, 1995; Abrams, 1998; Carter et al., 1999), in order to ensure effective, sustainable and equitable delivery to the users. From this analysis a water needs framework emerges (Figure 1).

Any evaluation must include both the 'perceived needs' of the users and a broader understanding of water needs derived from the literature

Water users have a perception of what their needs for water are. It is important to consider these 'perceived needs' because they will dictate which water sources people choose to use and are willing to pay for. Narayan (1995) has called for a demand-responsive approach to increase participation, ownership and project effectiveness. However, these 'perceived needs' are often limited to the quality, quantity, location and timing parameters of water uses because users frequently have little understanding of the supply system aspects of their water needs. In addition, there may be other aspects to their water needs that the users are entirely unaware of, which they therefore cannot articulate. For example, prior to the exposure of extensive groundwater As contamination, HTW users would not have known of their need for As-free water. Therefore any evaluation of a water system on the basis of how well water needs are met must include both the 'perceived needs' of the users and a broader understanding of water needs derived from the literature, represented here by the water needs

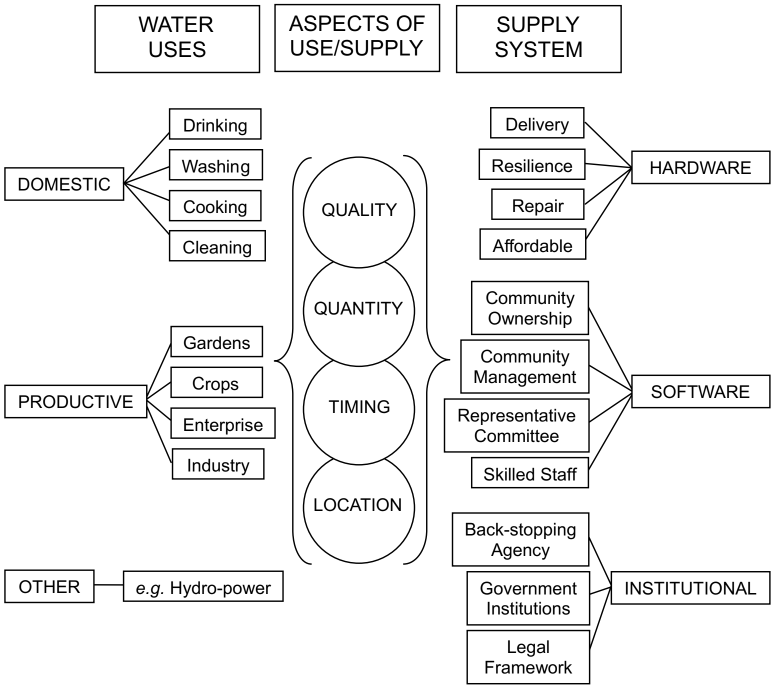

Figure 1. The water needs framework

framework. In this investigation, the framework provided lines of enquiry but users were also questioned directly about their water needs.

The villages and their MUS

> Users may subscribe to none, one or both water services

The three villages studied, Bashubehar, Magbari and Chandaikona, are located near Bogra, north-west Bangladesh. The houses conjugate in loose clusters, separate from the cropped land. This leads to a differentiation in water use between the irrigation and household water supply sections of the RDA MUS (Table 1). In fact, these are provided as separate services by the owners' groups, with separate tariffs (Tables 5 and 7), meaning that users may subscribe to none, one or both services. In all three villages the household water reservoir capacity is 30,000 litres and the pump capacities were 50 + 75 and 150 m^3/h for Bashubehar (2 DTWs) and Chandaikona (irrigation DTW), respectively. In theory, the household piped water is available 24 hours per day. The owners employ operators and drain men; during the *rabi* season these carry out irrigation according to sequenced schedules without the farmers needing to ask for water. During the *kharif* season irrigation is ad hoc, on demand. All the respondents interviewed said that they had access to a HTW, with only two not owning one. In the villages studied there were very few As-contaminated HTWs.

Bashubehar consists of three clusters of houses or *paras*. The RDA MUS, which includes two DTWs, is located in the middle *para* where 40 of the 55 households have a household connection. The irrigation command is 120 *bighas* (1 *bigha* = 1/3 acre). The owners' group has six members.

Magbari is a large, low-lying village. The RDA MUS is located in the eastern *para*; 11 of the 55 households are connected. At the time of study, this had recently reduced from 22 following a trebling of the household tariff. The system includes Fe and As removal plant as groundwater Fe levels are very high. The design command of 300 *bighas* has not been realized and only 150 *bighas* can be irrigated for various reasons discussed later. The owners' group has four members.

Chandaikona is a large village of approximately 400 households. The RDA MUS is unusual because there are separate DTWs for irrigation

Table 1. The purposes mentioned by the interviewees for which water supplied by the RDA MUS is used

Water supply section	*Use*	*Category of use*
Piped household water	Cooking	Domestic
	Washing clothes	Domestic
	Drinking	Domestic
	Washing dishes	Domestic
	Washing cattle	Domestic or productive
		Productive
	Watering poultry	Productive
	Watering cattle/livestock	Domestic or productive
	Watering plants	Domestic or productive
		Domestic
	Watering trees	Productive
		Domestic
	Wash floors	Domestic or productive
	Measure insecticides	Domestic or productive
	Bathing	Domestic
	Building houses	Domestic or productive
	De-husking rice	
	Toilets	
	Entertainment	
Irrigation water	*Rabi* season irrigation	Productive
	Kharif season irrigation	Productive
	Plant nursery	Productive
	Fish ponds	Productive
	Building work	Productive or domestic
	De-husking rice	Productive
	Bathing	Domestic

and household water supplies. There are 150 household connections with more constantly being added. Irrigation is limited to 132 *bighas* owing to aquifer yield; previous attempts to irrigate using LLDPs have failed because of large seasonal groundwater level fluctuations, which also severely affect HTWs. The owners' group has 23 members.

Methodology

The case study approach allowed the RDA MUS to be investigated within its real-life context. Only villages with RDA MUS were investigated but it was possible to fulfil the comparative requirements of the research by enquiring about the previous water supply systems and, in any case, not the entire population of each village was served by the MUS. Three villages were purposively selected from a short list of eight, based on the following criteria:

Only villages with designed MUS were investigated

- MUS fully operational for a minimum of 12 months – to ensure user experience during all seasons;
- ownership according to the RDA MUS village model, i.e. owners' group;
- a rural village;
- a range of functionality was sought, i.e. working or broken down.

Interviews were divided equally between men and women from each socio-economic group

The primary instrument of investigation was semi-structured interviews. A target of 20 interviews per village was set, with two interviews reserved for the chairman and operator and the remaining 18 divided equally between men and women from each socio-economic group according to the socio-economic profile (Table 6). The socio-economic groupings were determined from the literature and information provided by the village chairmen (Table 2).

The initial interviews were pre-arranged. Those that followed came through introduction or various forms of encounter as the researcher walked through the villages. Up to nine hours per day was spent in the villages, allowing direct observation of the villagers using water

Table 2. The socio-economic groupings used in this research

Socio-economic groupings chosen for this research	*Corresponding Bangladesh Bureau of Statistics (BBS)categories (Ali, 2007)*	*Bighas*	*Acres*
Landowners	Large/medium landholders	>7.5	>2.5
Small landowners	Small landholders	1.5-7.5	0.5-2.5
Workers	Functionally landless	<1.5	<0.5

Note: Landholding refers to ownership, therefore socio-economic grouping is determined primarily by land ownership.

and the water sources, houses and fields. Notes were made of any observations deemed relevant.

The interview information was augmented by various documents, including RDA publications, tubewell and plant designs, maps, pipeline plans, installation costs, budgets, cash books and others. Furthermore, RDA-led village meetings and training events were attended and RDA staff interviewed.

The information gathered was analysed by grouping the respondents' answers under the themes used for questioning, which were derived from the water needs framework. Summary tables were produced for each village and additional information not captured under the themes (e.g. from observations) was written up in a narrative or tabulated. Case study databases were formed for each village.

To establish rigour, three tests – construct validity, external validity and reliability – pertaining to descriptive case studies (Yin, 1994) were applied using:

- multiple sources of evidence: interviews, observation and documentation;
- multiple sources of data: many respondents interviewed;
- replication logic: three similar case studies;
- case study databases: formed for each village;
- chains of evidence: linking research findings to evidence in the databases.

Triangulation was possible on two levels: between the different sources of evidence and between the data sources, meaning respondents.

Despite these efforts to introduce rigour, it must be recognized that this remains a three-village case study investigating one MUS approach in a particular location and context. The conclusions drawn must be similarly limited.

Key findings and discussion

During June and July 2007, 84 interviews were carried out. The target number of interviews with men and women from each socio-economic group was achieved or exceeded in most cases. The exceptions were: Bashubehar, three women of the landowner group were interviewed instead of four; Magbari, no women of the landowner group were interviewed instead of two; Chandaikona, four women of the small landowner group were interviewed instead of five. Overall, 53 men and 31 women were interviewed compared with the target of 27 of each.

The users considered that the MUS met their needs for irrigation and domestic water better than their previous water supply systems

Figures 2 and 3 show the villagers' responses when asked if the RDA MUS meets their needs for irrigation and domestic water better than their previous water supply systems. Clearly, in both cases the users think that it does.

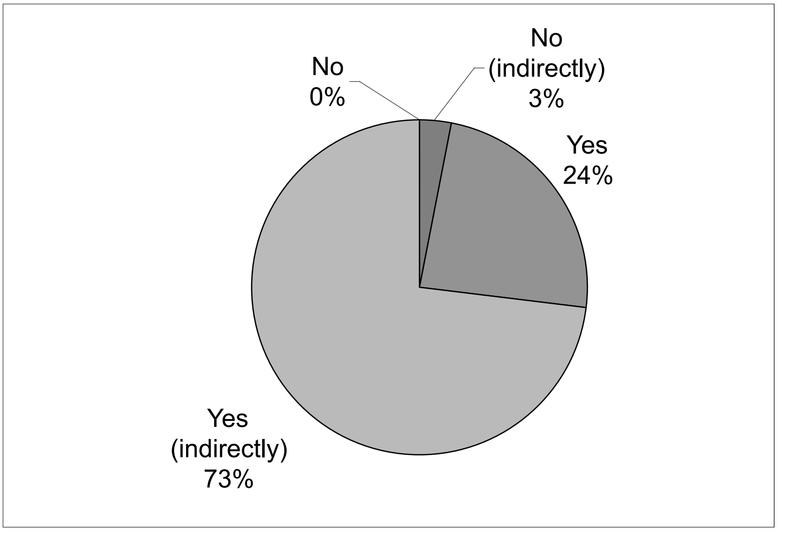

Figure 2. The responses given by the respondents when asked if the RDA MUS met their needs for irrigation water better than LLDPs

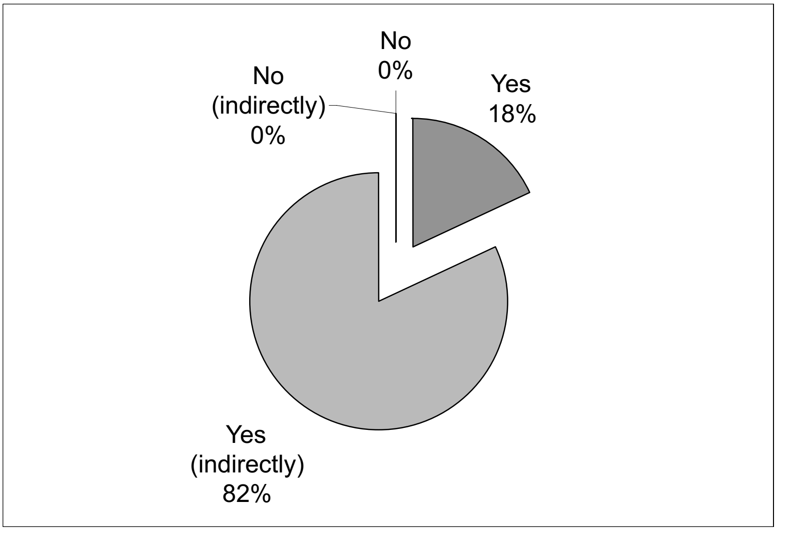

Figure 3. The responses given by the respondents when asked if the RDA MUS met their needs for household water better than the HTWs

The reasons given and the benefits of the RDA MUS over LLDPs varied significantly between the villages. In Bashubehar the main benefits were improved productivity and income through an increase in cultivable land and cropping intensity (crops/year), coupled with a reduced requirement for hard labour. In Magbari, lower costs and the opportunity to pay with cash as opposed to crop sharing were perceived as the main benefits. For Chandaikona the ability to irrigate allowing the production of rice and other crops leading to improved incomes was the overwhelming benefit. Across all the villages ease of access to household water and no pumping were major benefits of the RDA MUS over HTWs, although in Magbari the absence of Fe was considered the main benefit.

Ease of access to household water and no pumping were major benefits of the RDA MUS

Domestic water uses

Quality

The primary water quality issue relating to domestic use mentioned by many villagers was Fe. High Fe levels lead to a whole range of problems, for example staining clothes, darkening of teeth and nails. The impact of this is perhaps best captured in the comment: 'the HTW water gives the food a bad colour so that it looks like something else' a villager at Magbari (No. 5).

She was, of course, referring to faeces. The Fe led some villagers to use alternative water sources carrying a greater risk of faecal contamination (e.g. ponds), although not for drinking purposes. Despite not directly posing a health threat, clearly the villagers require water with a low Fe content, defined by the WHO guidelines as <0.3 mg/l (WHO, 2006). Only at Magbari were the groundwater Fe levels so high as to cause serious problems and here the RDA MUS with Fe/As removal plant was able to supply low Fe water, therefore meeting this quality need better than the HTWs.

Despite not directly posing a health threat, the villagers preferred water with a low Fe content

There were few comments, both negative and positive, about the taste and unfavourable temperature of the RDA MUS water. These were significant because they led to some users choosing to drink HTW water in preference to piped water. If the HTWs are contaminated with faecal microbes, as has been demonstrated in some cases (Macdonald et al., 1999; Hoque et al., 2006) this would negate many of the benefits of a piped water supply. Of course, the RDA MUS water may also be contaminated with faecal microbes. No water quality testing was carried out but the frequent interruptions in water supply at Magbari and Chandaikona suggest that contamination is a possibility. This should be investigated further.

Clearly, taste or, more pertinently, the perception of taste and temperature are important aspects of quality needs and, given the few negative comments made, it would seem reasonable to conclude that the RDA MUS meets this aspect of need in the villages studied.

Quantity and location

The RDA MUS provided greater quantities of domestic water needs than HTWs

When asked if the RDA MUS was able to provide enough water for their domestic uses 85 per cent of the respondents answered 'yes'. In contrast, they said that pumping water was hard, especially during the dry season when many were unable to access enough water, particularly in Chandaikona. Therefore the RDA MUS does appear to meet the quantity aspects of domestic water needs better than HTWs.

Increased service level of access can lead to significant public health gains because when water is provided closer to homes, more water is used for hygiene purposes (Howard and Bartram, 2003). For most users the RDA MUS tap and HTW are sited in the same location, the household yard, described as 'intermediate access' (ibid.); only the wealthier have multiple and interior taps, defined as 'optimal access' (ibid.). There were mixed responses from the villagers when asked if the volume used had changed with the advent of a piped water supply. Clearly the locational aspect of need can be better met by the RDA MUS if taps are fitted inside the house, which would likely also further enhance the quantity aspect of needs.

Timing

When people needed water from the MUS sometimes it was not available

The critical timing element that emerged with the RDA MUS was related to interruptions to supply; that is, when people need water sometimes it is not available. Most frequently this occurs because the overhead tank is empty during a power cut. This is a management problem as it is the responsibility of the operators to ensure the tank is full. In Magbari and Chandaikona they often fail to fulfil this responsibility, although there are complicating circumstances with breakdowns and high connection numbers. Apart from access difficulties during the dry season, HTW water is always available and the timing issue relates more to the length of time taken to pump the water.

In conclusion, the RDA MUS does not meet the timing aspects of domestic water needs better than HTWs, because of the reliance on electricity.

The combination of a RDA MUS and HTWs is perhaps the ideal; one provides improved quality, quantity and access while the other is always available. This is already happening, as all the interviewees said they had access to a HTW, with only two not owning one, but is not without problems. There are significant costs associated with HTWs, discussed below, and when not used regularly HTWs seize up very quickly.

Productive water uses

Quality

The only irrigation water quality issue encountered was Fe, which can make the fields look yellow and block irrigation pipes. Opinion was mixed as to the effect of this on crops. No conclusions could be drawn about how well the quality aspect of needs is met by the RDA MUS.

Quantity

The advent of the RDA MUS meant that there was more irrigation water available

In Bashubehar and Chandaikona the advent of the RDA MUS meant that there was more irrigation water available, hence more land was irrigated and cultivated leading to increased production and incomes. This increased quantity is not only due to the source of water used (i.e. DTWs compared with surface water and STWs), but also because losses are reduced by employing a pipeline for distribution. However, quantity cannot be disassociated from the timing and locational aspects.

Timing and location

It is the availability of irrigation water during the *rabi* or dry season that is crucial. Without irrigation at this time, rice and other crops requiring irrigation cannot be cultivated. Moreover, *boro* rice cultivated during the *rabi* season is higher yielding than rice grown at other times of year, because of the longer growing season. Regarding location, it is the ability of the pipe system to deliver water to land that previously could not be reached using open channels that has allowed the cultivated area to increase at Bashubehar. There is still a dependence on open channels and when these are not in serviceable condition certain locations cannot be irrigated. This is true for the RDA MUS and LLDPs.

Magbari is different from the other villages. There were few comments suggesting that more water was provided by the RDA MUS or that cultivated land area and cropping intensity (crops/year) had increased. Instead the RDA MUS struggled to supply water to certain locations, namely the higher land. This affected the timing aspect because irrigating these areas was slower, therefore the time to complete each irrigation cycle was extended, and the irrigation intervals were stretched. The net result is that the design irrigation command has not been realized. Across all the systems, capacity is limited by the availability of electricity. Power cuts mean that adequate irrigation intervals are not always maintained. As a result, crop irrigation timing requirements are not met nor are design command areas achieved. Thus the timing aspect of needs is not always met by the RDA MUS.

Power cuts mean that adequate irrigation intervals are not always maintained

To conclude, the RDA MUS has the potential to meet the quantity, timing and location aspects of irrigation needs more effectively than LLDPs, with significant impacts on productivity and income, but this does depend on the topography of the site. LLDPs appear to perform very adequately at low-lying sites such as Magbari. The performance of the RDA MUS with regard to timing is subject to interruptions in the power supply.

Supply system: hardware

Resilience and ease of repair

Other than the treatment plant at Magbari, few serious, repeating breakdowns were reported. The impression given was that those that did occur, occurred infrequently, were repaired quickly and easily, often in house, with relatively little interruption. So the evidence suggests the systems are reasonably resilient and easy to repair. This cannot be said of the Fe and As treatment plant.

The systems are reasonably resilient and easy to repair

At the time of study, the treatment plant at Magbari had been non-functional for two months. The problems mentioned by the owners include the booster pumps, filter, air compressor and valves, and they attribute these to the high Fe levels, although other sources dispute this. Whatever the precise nature of the problems, three things are clear: the treatment plant is not resilient to the conditions it operates in, the problems are multiple and they are beyond the capacity of the operator and owners to repair.

HTWs are also subject to frequent breakdowns (Table 3). Little information was obtained regarding the resilience and ease of repair of

Table 3. Summary of the installation costs, breakdown frequency and repair costs of HTWs given by the respondents

Village	*Interviewee reference No.*	*Breakdown frequency*	*Component parts breaking down*	*Cost (Tk) per installation / breakdown*
Installation				
Bashubehar	Chairman			3000
Chandaikona	No. 6			5000
Breakdowns				
Bashubehar	Chairman	Every 1–2 years	Pipes	1000
Chandaikona	No. 11	5–7 times/year	Pipes	1500–2000
Chandaikona	No. 12	Every 2–3 months	Valves	200–300
Chandaikona	No. 18	Every 6–12 months	Valves	50–60
Chandaikona	No. 22	No breakdowns		
Chandaikona	No. 24	2 times/year	Valves & 'bucket'	50
Chandaikona	No. 26	Every 6–12 months	Valves	10–15

US$1 = 69 Bangladesh taka (Tk); November 2009

LLDPs, and it cannot be determined from his study whether these system needs are met more effectively by the RDA MUS than the previous supply systems.

Affordability

No capital repayments (except the initial down payment) have been made in Magbari and Chandaikona, and Bashubehar is far off schedule with repayments (Table 4). In Magbari, this is despite the fact that the RDA reduced the monies due to 50 per cent of capital costs. Furthermore, only in Bashubehar has a profit margin been possible, so it seems that the RDA MUS are not affordable for the communities, at least not in a 10 year timeframe. The RDA itself remains financially viable because these MUS form part of a GoB supported action-research programme.

The MUS are not affordable for the communities, in a 10 year timeframe

The failure to recover costs may in part be due to the considerable additional investments the owners have had to make after the MUS have been installed (Table 4). More importantly, the design irrigation command has not been achieved in Magbari and Chandaikona, because of design faults and aquifer yield, respectively, which clearly affects revenue generation and affordability. This is exacerbated by the effect of electricity cuts on irrigation command.

The irrigation tariffs and costs are shown in Table 5. Over 70 per cent of the respondents said that the irrigation tariffs were reasonable and none said they were unaffordable. Indeed, at Magbari the reduced irrigation cost was the main benefit of the RDA MUS and there is scope for increasing the tariffs to cross-subsidize household tariffs and improve revenues.

None of the respondents said that the irrigation tariffs were unaffordable

Table 4. The capital costs of the RDA MUS and repayments made up to July 2007.

	Bashubehar	*Magbari*	*Chandaikona*
Year of installation	1998	2005	2001 & 2005
Installation cost (Tk)	840,042	1,800,000	2,712,992
10% down payment (Tk)	84,000	180,000	264,000
Total capital repayment due (Tk)	840,000	900,000	2,712,992
Repayment schedule: 10% capital costs/year (Tk/year)	84,000	90,000	271,299
Capital repaid to July 2007 (Tk)	420,000	180,000	264,000
Additional investment by owners (Tk)	145,000	28,272 + cost of 323 m irrigation pipe	1,220,000

Sources: RDA and owners groups ($1 = 69 Bangladesh taka (Tk); November 2009)

Table 5. Irrigation tariffs and unit costs for the RDA MUS and LLDP

Irrigation tariffs	*Rabi season (charged per season)*	*Kharif season (charged per pass)*
Bashubehar	Tk561/bigha	Tk133/bigha
Magbari	Tk867/bigha	Tk50/bigha
Chandaikona	25% crop ≡ Tk2000/bigha	Tk100/hr
Previous system, LLDP	25% crop ≡ Tk2000/bigha (hired pump) Tk1000-1200/bigha (owned pump)	67-150 Tk/bigha
Irrigation unit costs	Diesel	Electricity
Fuel or power cost/bigha	Tk63	Tk20

Notes: 25% of crop is calculated as Tk2,000 from a yield of 20 *maund*/*bigha* and a price of Tk400/*maund (ex-farm, June 2007)*. Various figures were given for electricity charge/unit (e.g. Tk2.87/unit). (Unit conversions: \$1 = Tk69; November 2009; 1 *bigha* = 1/3 acre; 1 *maund* ≈ 40 kg)

Table 6. The socio-economic profile of the villages (provided by the chairmen) and the percentage of interviewees from each socio-economic group with a household connection

	Bashubehar		**Magbari**		**Chandaikona**	
Socio-economic group	*% of village population*	*Interviewees with a household connection %*	*% of village population*	*Interviewees with a household connection %*	*% of village population*	*Interviewees with a household connection %*
Landowner	50	88 (7/8)	25	75 (3/4)	22	75 (6/8)
Small landowner	50	0 (0/7)	25	58 (7/12)	53	64 (7/11)
Worker		33 (2/6)	50	14 (2/14)	25	14 (1/7)

Cost is the main reason why the villagers are not connected to the RDA MUS household supply

Cost is the main reason why the villagers are not connected to the RDA MUS household supply. This is reflected in the low proportion of 'workers' connected (Table 6) and stands in contrast to universal HTW access. The 'workers' perceive that they cannot afford to be connected. But is this actually the case?

Respondents were questioned about their incomes and 'workers' typically earn Tk1500-3000/month. This may be partially paid in rice or supplemented with meals. One female worker reported being paid as little as Tk30/day, supplemented with three meals. The 'small landowners' often reported incomes similar to, and sometimes less than, the workers, ranging from Tk500 to Tk8000/month. However, the respondents were most likely only referring to their cash income from employment and not any income earned from cultivating crops on their landholdings (Table 2).

When the water industry rule of thumb, which says that a spend of 5 per cent of household income on domestic water and sanitation is affordable (Franceys et al., 2006), is applied to the household tariffs

Table 7. Household water tariffs and the percentage of income spent on water

	Tariff per head/month Tk	*Tariff for 5-person hh/month Tk*	*% of monthly household income*		
			Tk3,000	*Tk2,000*	*Tk1,000*
Bashubehar	10	50	1.7	2.5	5
Magbari	30	150	5	7.5	15
Chandaikona		115	3.8	5.8	11.5

Note: This analysis ignores sanitation and connection costs, which are included in the rule of thumb.

(Table 8), it is apparent that for many 'workers' these tariffs are unaffordable, although perhaps not for those earning Tk3,000/month. The 50 per cent reduction in connections following the trebling of tariffs at Magbari demonstrates this since this is where 'workers' form up to 50 per cent of the population (Table 6).

But how relevant is this type of analysis for those who carry the daily burden of feeding their families? One landless woman with a household of five, whose husband earns Tk3000 per month, confided:

'We spend Tk100 per day on food.' *(Villager at Magbari, No. 30)*

Others said a household of seven consumes 4kg rice per day, which at Tk20/kg (wholesale, June 2007) amounts to Tk80/day. For the 'workers', after paying for food, not much cash remains and so the thought of paying for piped water when there is a HTW outside the house providing 'free water' is absurd.

But of course, HTW water is not free, as demonstrated in Table 3. These figures show that the costs (capital and recurring) of a HTW are comparable to a household connection (Tk1,000–6000 for pipes, fittings etc. plus Tk520 connection charge at Chandaikona). Perhaps this is why the husband of interviewee 23 (Chandaikona), who earns Tk100/day pulling a rickshaw, chose to invest in a piped water supply rather than a HTW. For him the costs were:

Installation and fittings	Tk2,200
Connection charge	Tk520
Monthly tariff	Tk115

For many the tariffs are unaffordable but this may be a perception issue

So, although for many the tariffs at Magbari and Chandaikona really are unaffordable (according to the 5 per cent rule) this is also a perception issue. Perhaps many do not consider the costs of owning a HTW. Linked to perception, some have other spending priorities and this featured as a major reason for not being connected. One chairman of an owners' groups commented: 'Those who say Tk100 water charge is hard to pay, pay Tk150 for cable TV'.

Supply system: software and institutional aspects

Community ownership

Where governments are unable to deliver water services, a sense of community ownership, fostered by participation, is vital for the success and sustainability of development projects (Carter et al., 1999). The motivation of the community is essential because there is no one else to make the intervention work (ibid.). In the RDA MUS model the situation is different. Although owned by members of the community, the systems are not owned by the community as a whole, and the motivation to make it work is a profit incentive. This is not a problem per se, but it does raise some issues.

Owners groups: some of the issues

The owners' groups are not representative of the communities

The owners' groups are not representative of the communities. They are small groups of people, sometimes all family, who have: 'land, authority and influence' (chairman of an owners' group).

The owners' group in Chandaikona is larger but the 'workers' are excluded by default as they are unable to make the investment required. Despite mention of open meetings, the evidence that the users participate or have influence over the decisions made is sketchy and within the owners' groups, the chairmen make most of the decisions: 'there is no need for a discussion with the users as the same price is maintained afterwards' (chairman of an owners' group).

The involvement of non-owners or employees in the decision making of a private enterprise would not normally be considered necessary. However, as water provision is an essential service, there have to be mechanisms to protect the dependants from exploitation and incompetence. These are usually regulations and enforcement bodies but in Bangladesh there is no legal framework governing water provision by private operators in rural villages (RDA staff, personal communication). When asked who the owners' group are accountable to, one chairman replied: 'the village people criticise'.

Virtually all respondents considered irrigation water distribution to be fair and so there seem to be social factors that influence and constrain the owners. 'If the distribution was unfair, the people would kill them [the owners]' (villager at Magbari; No.14).

However, this does not prevent them from making unpopular or detrimental decisions, such as trebling household tariffs at Magbari, or from favouring friends and relatives.

Capacity, training and a back-stopping agency

The decisions made by the owners' group are also affected by their capacity. Although both operators and owners receive RDA training, the evidence of rudimentary misunderstandings and mistakes, for example the expectation that household connections can increase indefinitely with just one tank, suggest that the owners lack the skills and training required for their role as water providers. Various researchers (e.g. Abrams, 1998) have stated the importance of back-stopping agencies providing continued support for ensuring sustainability. In many ways the RDA fulfils this role but there is room for improvement: for example, the treatment plant at Magbari had been out of action for two months. More fundamentally, the owners' groups are left entirely to their own devices when they need guidance and instruction.

Back-stopping agencies are needed to provide continued support to ensure sustainability

'Water lords'

Once the RDA MUS are installed the strings of power are held by the chairman and owners. This is remarkably reminiscent of a World Bank DTW project in Bangladesh in the 1970s, where virtually all the DTWs were monopolized by the wealthy (Hartmann and Boyce, 1983). Again the wealthy and influential are in control. As it is unacceptable for LLDP owners to hire out their machines within the command of another irrigation scheme, those whose land falls within the RDA MUS command are forced to subscribe to it.

> 'Every pump has a project area, so I cannot put my diesel engine in another project area' (villager at Magbari, No. 7).
>
> 'We have a new diesel engine for irrigation but we do not use it because if we use our own pump some other people will also use their own diesel pump – that would be chaos' (villager at Magbari, No. 14).

So these men of 'land, authority and influence' who have become owners of the RDA MUS are able to extend their powers to include village water provision. The term 'water lord' was voiced by several informants.

Men of 'land, authority and influence' were able to extend their powers to include village water provision

Although social factors exert some control over the owners' groups, the lack of representation, minimal participation and absence of regulation means the interests of the users are not protected. Because the power over water provision is held by the wealthy and influential, and irrigation users within the command have no choice but to subscribe, the users are vulnerable. This vulnerability is exacerbated by the owners' lack of skills in water management and the absence of guidance and instruction. In conclusion, the effectiveness, sustainability and equity of water supply are undermined to varying degrees by the software and institutional elements: ownership, management, representation, skilled staff, back-stopping agency and the legal framework. Clearly there are deficiencies in the way the RDA MUS meets these aspects of water needs.

Conclusions

The purpose of this study was to determine whether the RDA MUS meets the people's needs for water better than the HTWs and LLDPs. No conclusion can be reached on whether the RDA MUS achieves this because there is insufficient comparative information pertaining to the supply system aspects of water needs.

However, the clear message from the users is that the RDA MUS does meet their needs for irrigation and household water better than the HTWs and LLDPs. The benefits for the users have been improved productivity and incomes, lower irrigation costs, easier access to domestic water and water that is Fe free. From the analysis it is apparent that most of the water users' needs are indeed better addressed by the RDA MUS than the previous water supply systems, with some exceptions relating to timing.

The poor have less access to a RDA MUS household supply as for many the tariffs are unaffordable

The systems are not affordable for the communities over a ten year timeframe, so the anticipated potential for the financial benefits of the MUS to aid cost recovery has not been realized. Furthermore, the poor have less access to a RDA MUS household supply as for many 'workers' the tariffs are unaffordable, although for others this is a matter of perception and priorities. This contrasts strongly with almost universal ownership of HTWs.

The RDA MUS does not adequately address the software and institutional aspects of water needs. The problems discussed potentially undermine the effectiveness, sustainability and equity of water supply because the interests of the users are not protected, leaving them vulnerable to powerful owners who control the water supply but lack skills, training and supervision.

In summary, though the RDA MUS is appreciated by the users and has brought them real benefits, meeting many aspects of their water needs more effectively, there are problems with the model that leave the users vulnerable, the owners struggling with capital repayments and many of the 'worker' socio-economic group unable to access the benefits of a household connection. These problems will need to be addressed if the potential benefits of the RDA MUS are to be fully realized.

References

Abrams, L.J. (1998) 'Understanding sustainability of local water services' [online], available from: http://www.africanwater.org/sustainability.htm [accessed 27 July 2009].

Ahmad, K.M., Bhattacharya, P., Hasan, M.A., Akhter, S.H., Alam, S.M.M., Bhuyian, M.A.H., Imam, M.B., Khan, A.A. and Sracek, O. (2004) 'Arsenic enrichment in groundwater of the alluvial aquifers in Bangladesh: an overview', *Applied Geochemistry* 19: 181–200.

Ali, A.M.S. (2007) 'Population pressure, agricultural intensification and changes in rural systems in Bangladesh', *Geoforum*, 38(4), p. 720-738.

APSU (2006) *Selected Papers on the Social Aspects of Arsenic and Arsenic Mitigation in Bangladesh* [online], Arsenic Policy Support Unit, Dhaka, Bangladesh, available from: http://www.physics.harvard.edu/~wilson/arsenic/references/selected_social_papers.pdf [accessed 5 August 2009].

Carter, R.C., Tyrrel, S.F & Howsam, P. (1999) 'Impact and sustainability of community water supply and sanitation programmes in developing countries', *Journal of the Chartered Institute of Water and Environmental Management* 13: 292–6.

Franceys, R., Fonseca, C. and Perry, C. (2006) *African Development Bank: Guidelines for User Fees and Cost Recovery for Water, Sanitation and Irrigation Projects* [online], Draft Guidelines, available from: www.afdb.org [accessed 28 August 2007].

Hartmann, B. and Boyce, J.K. (1983) *A Quiet Violence: View from a Bangladesh Village*, Zed Books, London.

Hoque, B.A., Hallman, K., Levy, J., Bouis, H., Ali, N., Khan, F., Khanam, S., Kabir, M., Hossain, S and Alam, M.S. (2006) 'Rural drinking water at supply and household levels: quality and management', *International Journal of Hygiene and Environmental Health* 209: 451–60.

Hossain, F., Bagtzoglou, A.C., Nahar, N. and Hossain, M.D. (2006) 'Statistical characterisation of arsenic contamination in shallow tube wells of western Bangladesh', *Hydrological Processes* 20: 1497–1510.

Howard, G. and Bartram, J. (2003) *Domestic Water Quantity, Service Level and Health* [online], WHO, Geneva, available from: www.who.int/water_sanitation_health/ [accessed 22 May 2007].

IWMI (2004) *Pro-poor Interventions in Irrigated Agriculture in Bangladesh: Issues, Options and Proposed Actions* [online], International Water Management Institute (IWMI), Colombo, Sri Lanka, available from: www.iwmi.cgiar.org [accessed 16 July 2007].

IWMI (2006) *Taking a Multiple-use Approach to Meeting the Water Needs of Poor Communities Brings Multiple Benefits* [online], Water Policy Briefing, Issue 18, International Water Management Institute (IWMI), Colombo, Sri Lanka, available from: www.iwmi.cgiar.org/waterpolicybriefing/index.asp [accessed 16 July 2007].

Kayaga, S., Calvert, J. and Sansom, K. (2003) 'Paying for water services: effects of household characteristics', *Utilities Policy* 11: 123–32.

Macdonald, D., Ahmed, K.M., Islam, M.S., Lawrence, A. and Khandker, Z.Z. (1999) 'Pit latrines: A source of contamination in peri-urban Dhaka? *Waterlines* 17(4): 6–8.

Narayan, D. (1995) 'The contribution of people's participation: evidence from 121 rural water supply projects', *Environmentally Sustainable Development Occasional Paper Series, No.1*, World Bank, Washington, DC.

Smits, S., Moriarty, P.B., Butterworth, J.A., Restrepo, I., van Koppen, B. and Cousins, T. (2004) 'Towards multiple use water services', background paper for E-conference: *Tackling poverty through Multiple Use Water Services*, IRC International Water and Sanitation Centre, Delft, The Netherlands.

UNDP (United Nations Development Programme) (2006) *Human Development Report 2006. Beyond Scarcity: Power, Poverty and the Global Water Crisis* [online], United Nations Development Programme (UNDP), New York, available from: www.hdr.undp.org/hdr2006/ [accessed 19 July 2007].

van Koppen, B., Moriarty, P.B. & Boelee, E. (2006) *Multiple-use Water Services to Advance the Millennium Development Goals,* Research Report 98 [online], International Water Management Institute, Colombo, Sri Lanka, available from: www.iwmi.org [accessed 22 May 2007].

WASH (1994) *The Sustainability of Donor-assisted Rural Water Supply Projects*, WASH Technical Report No. 94 [online], Water and Sanitation for Health Project, available from: http://pdf.usaid.gov/pdf_docs/PNABQ942.pdf [accessed 27 July 2009].

WHO (2006) *Guidelines for Drinking-water Quality: Incorporating First Addendum*, Vol. 1, *Recommendations* (3rd edn) [online], available from: http://www.who.int/water_sanitation_health/dwq/gdwq3rev/en/ [accessed 23 November 2009].

Yin, R.K. (1994) *Case Study Research: Design and Methods*, Applied Social Research Methods Series, Vol. 5, Sage Publications, London, 2nd edn.