Community finance and promotion of Managed Aquifer Recharge systems affect uptake and sustainability as a potable water source in southwest coastal Bangladesh: A qualitative study

Fosiul A. Nizame (fosiul@icddrb.org)
icddr,b

Fosiul Alam Nizame
International Centre for Diarrhoeal Disease Research Bangladesh

Md. Abu Naser
International Centre for Diarrhoeal Disease Research Bangladesh

Afsana Sharmin
International Centre for Diarrhoeal Disease Research Bangladesh

Tania Jahir
International Centre for Diarrhoeal Disease Research Bangladesh

Solaiman Doza
International Centre for Diarrhoeal Disease Research Bangladesh

Mahbubur Rahman
International Centre for Diarrhoeal Disease Research Bangladesh

Leanne Unicomb
International Centre for Diarrhoeal Disease Research Bangladesh

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Abstract

Background

In the south-western coastal region of Bangladesh ground water, normally used for drinking, is excessively saline. Increased salinity in drinking water can have a range of adverse health impacts. Managed aquifer recharge (MAR) systems, which infiltrate rainwater and fresh pond water into aquifers, are adaptive strategies to deliver low-saline water to the affected communities. Several MAR systems have been piloted in these regions. The MAR pilot study demonstrated the potential for increasing freshwater availability and sustainable year-round drinking water supplies. The objective of this study was to identify MAR system management shortcomings and strengths to provide recommendations that are applicable for future MAR systems and engineering driven water management methods in low-income countries.

Methods

A qualitative study among the 18 pilot MAR communities with access to MAR systems since 2010 was conducted to assess perceptions of drinking MAR water and usage patterns. We conducted in-depth interviews (24), key informant interviews (2) and focus group discussions (3).

Results

More than half (13) of the respondents reported that drinking saline water causes diarrhea, dysentery, gastritis, digestive or abdominal disorders none described impact on blood pressure. More than two thirds (13/18) of current MAR users reported MAR as their preferred drinking water source. Almost half (11) reported that they were familiar with MAR but don’t understand how it works. A majority of respondents (17) considered MAR water safe because they thought there are no germs present. Nonetheless, respondents mentioned several problems including dissatisfaction with water quality (salinity/iron/smell/dirt in the water), and management (MAR sites found locked for most of the day). MAR installation and management staff and technical supervisors and caretakers thought that water quality was hampered by irregular water infiltration. They reported that management and maintenance issues were their primary concern, which were impeded by limited funds, as users do not pay regularly.

Conclusions

Though there is a demand for drinking water from MAR systems, the concerns about management related to finance, in addition to the amount collected are the greatest threat to system functionality and sustainability, which requires community-based solutions that will provide regular oversight and maintenance.

Introduction

The south-west coastal Bangladesh faces a crisis of fresh drinking water due to ground water salinity [1, 2] This region is more vulnerable to safe drinking water shortage than elsewhere in the country because both surface and ground water suffer from acute and high salinity intrusion [1]. Pond water, which is microbiologically contaminated [3], is a common low-saline alternative drinking water source in this region [4, 5]. Ponds can also be saline, especially after inundation from severe storms [6]. Groundwater salinity has been associated with increased sodium intake through drinking water in coastal Bangladesh estimates suggest up to 16 gm sodium intake per day only through drinking water [7]. Increased salinity in drinking water is likely to have a range of adverse health impacts [8–12]. Epidemiological studies have demonstrated that high sodium intake is associated with elevated blood pressure and cardio vascular diseases [13]. Moreover, drinking pond water that is contaminated and unclean poses a risk for diarrheal and other water-borne diseases. Filtration methods such as biosand or pond sand filters (BSF/PSF), a point of use (POU) water treatment method, can be used at individual household or at community level [14, 15]. To meet fresh drinking water crisis needs, different strategies were taken in the coastal areas of Bangladesh including PSF [16]. Community engagement is important when selecting new technologies to encourage uptake and to sustain their use [6, 17].

To mitigate drinking water salinity, an adaptive strategy known as Managed Aquifer Recharge (MAR), has been demonstrated in a series of successful installations across south-west coastal Bangladesh. Freshwater derived from monsoon rain is injected into shallow coastal aquifers [18]. The Geology Department of the University of Dhaka, in collaboration with Unicef piloted 18 MAR projects, in three districts of south-west Bangladesh; Khulna, Shatkhira and Bagerhat [6].The MAR pilot study demonstrated the potential for increasing freshwater availability and sustainable year-round drinking water supplies. Subsequently 80 MAR systems have been installed in these regions and a health impact evaluation of MAR water access on blood pressure and kidney function has recently concluded [1, 6, 19, 20].

In this study we enrolled members from 18 MAR pilot communities to explore water source preference, MAR water and system acceptability to explore factors affecting MAR use. The objective of this study was to identify MAR system management shortcomings and strengths to provide recommendations for future management that are potentially applicable to other engineering driven water management methods in low-income countries.

Methods

Study site and period: In 2016, during the dry season (March and April), we conducted a qualitative assessment among the 18 pilot MAR communities in Khulna, Shatkhira and Bagerhat. The MAR sites were open for water collection between March to April, 2010 and all 18 were still in operation during the study period.

Study design and sampling: We used a qualitative research approach, consisting of in-depth interviews (IDIs), key informant interviews (KIIs) and focus group discussions (FGDs). To maximize data variability,

the sampling framework included three MAR sites per district selected based on groundwater salinity, sites categorized as having high, low and median electrical conductivity (EC) at pilot phase, giving a total 9 pilot sites (Table 1). The Focus group discussions included the technical supervisors and caretakers (recruited from same community) of all 18 pilot MAR sites, for a total of 3 FGDs; one in each of the three districts. Our key informants included the key personnel from the Dhaka University team who are responsible to oversee the MAR implementation in the field. IDI interview and FGD sample sizes were determined from data saturation attainment in previous water, sanitation and hygiene qualitative studies [21–23].

Table 1
Initial Electro Conductivity (EC) of selected MAR sites

Sites/Districts	Highest initial EC (uS/cm)	Median initial EC (uS/cm)	Lowest initial ECs (uS/cm)
Bagerhat	15.54	7.04	4.11
Khulna	14.30	4.70	2.79
Shatkhira:	11.42	5.82	3.40

The field team purposively enrolled two households from each of 9 selected MAR sites based on approximate distance (close, intermediate and far) from the MAR system and MAR user category; determined during respondent selection by interviewer with the help of MAR staff, and also attempted to ensure variation of household economic status. Research Officers conducted IDIs with one adult member from each household who usually manages/collects drinking water for his/her household. From each district, we conducted 6 IDIs (3 MAR sites X 2 IDIs), therefore in total 6 × 3 = 18 IDIs with MAR users. Additionally, we enrolled two further households in each of the three districts from the 3 selected MAR sites (high, low and median salinity level (EC)) to include one former MAR user and one never user. Thus, a total of 8 IDIs were conducted in each of 3 districts, a grand total of 24 IDIs (3 district X 8 IDI’s) (Table 2).

Table 2
Demographic characteristics, and drinking water sources of the MAR site in-depth interview respondents:

Indicator	**User N = 18**	**Former user N = 3**	**Never user N = 3**	**Total N = 24**
Age (years)				
18–28	4			4
28–38	4	2	2	8
38–48	6		2	8
> 48	4			4
Education				
No formal education	3	1		4
Up to primary level	4	1	1	6
Secondary level	10	1	1	12
Graduate	1		1	2
Profession				
Home maker	10	3	3	16
Business	3			3
Shopkeeper	1			1
Daily laborer	2			2
Medical representative	1			1
Private service holder	1			1
Household monthly income in BDT*				
≤ 5000	6	1		7
5001–10000	6	1	1	8
10001–15000	4			4
> 20000	1	1	2	4
Unknown				1
Sex				

*In 2016, 1 USD = 80 BDT

Indicator	User N = 18	Former user N = 3	Never user N = 3	Total N = 24
Male	5			5
Female	13	3	3	19
Current drinking water sources				
MAR	13			13
Canal	1			1
Pond	3	1	1	4
Pond sand filter	5	2	3	10
Purchased pond water supplied by vendor	1			1
Preferred drinking water sources				
MAR	13			13
Rain	3	1		4
Pond	1			1
Pond sand filter	1	2	3	6
*In 2016, 1 USD = 80 BDT				

We conducted two KIIs to obtain MAR installation and management staff's views on the strengths and weaknesses of MAR systems, the community's attitude towards MAR through their experience over the years and their suggestions for the future.

Data collection : Interview guidelines were developed according to study objectives: identifying MAR system management shortcomings and strengths, to provide recommendations. This was done for each data collection method guided by the Integrated Behavioral Model for Water, Sanitation and Hygiene (IBM-WASH) theoretical framework. IBM-WASH integrates the multi-level factors influencing water, sanitation and hygiene behavior, in three dimensions; contextual, psychosocial and technological [24].

Four researchers with experience conducting qualitative research carried out data collection in Bengali, the local language. During data collection, we explore their perspective on MAR water including their views on taste/quality, barriers to using and maintaining MAR system, their opinion on sustainability and maintenance of MAR sites as well as sources of drinking/cooking water during the dry season, and the cost of managing fresh drinking water in dry season. Through IDIs with the former users and never-users, we also sought their opinion on the MAR system, reason for non-use and suggestions to improve MAR

systems to increase the number of MAR users. The three focus group discussions with the Technical Supervisors and caretakers from all of the 18 pilot MAR sites aimed to assess their understanding about the MAR system, their perspective on the community's attitude towards the MAR system, about the intervention's strengths and weaknesses to elicit suggestions for sustainability and strengthening the intervention.

Data Analysis

All the interviews and group discussions were recorded using digital recorders after taking written consent from the participants prior to commencing. We manually identified code themes according to our research objective and summarized relevant information in English directly under each code by listening to data on the recordings. Each of the interviews and discussions were separately summarized following the same method. We compiled all data under each theme for all the IDIs, FGDs and KIIs separately. We conducted thematic content analysis and provide a brief description of our findings.

We analyzed these data using the IBM-WASH framework dimensions and levels. Where applicable, we analyzed the results according to the contextual, psychosocial and technological dimensions, at the community, behavioral, interpersonal, and individual levels.

Ethical considerations

Data collectors explained the research study objectives clearly to study participants reading the content of consent forms. Before taking part in the study, these participants provided written informed consent which was documented by a signature. The protocol for this study was reviewed and approved by the icddr,b Institutional Review Board, protocol number PR-15096.

Results

Respondents' socio-demographic characteristics

IDI respondents were mostly female (19/24), one third were between 18- 28 years old and another third was between 28 to 38 years of age. Almost half of the respondents completed primary level education. Two-third of our respondents were homemakers and one third of the households earned US$ 62.50 to US$ 125 per month. One-third of the households were living in the community for between 21 and 40 years (Table 2). Among the 28 focus group discussion participants (technical supervisors and caretakers recruited from same community) more than half (16/28) completed a bachelor's degree and more than half (16/28) were living in the same community where they were managing MAR site for more than 25 years. The both key informants (MAR installation and management staff) had post graduate degrees.

As we found quite similar responses between the groups; current user, former user and never user, we present combined findings.

Salinity impact on human and animal health

An important motivator for developing the MAR system and therefore an important element of MAR management was the perceived health benefits of drinking low saline water. Thus, we explored health impact perceptions. More than half (13) of respondents reported that drinking saline water causes diseases such as diarrhea, dysentery, gastritis, digestive or abdominal disorders; none described impact on blood pressure. Some (4) could not name a specific health hazard related to water salinity. About one third of respondents (9) mentioned that saline water also affects animal health and has a negative impact on the environment. They said that livestock (cows and goats) suffer from diarrheal disease from drinking saline water. Two respondents mentioned that salinity hampers optimal crop and plant growth. One mentioned that fish die in saline water. However, one current user from Khulna mentioned that,

> *"Saline water is not so harmful because saline can be removed from the body but it is not possible to remove arsenic"*

Preferred water sources for drinking

More than two thirds (13/18) of current MAR users reported MAR as their preferred drinking water source, 3/18 users and 1/3 former user preferred rain water (Table 2). One user said,

> *"I prefer MAR water than other water sources because quality of MAR water is better. But sometimes its quality deteriorates because iron comes up with water. I think it happens because pond water is mixed with ground water in MAR."*

However, some (6; 1 current, 2 former and 3 never user) respondents preferred water from pond sand filters. One former user stated:

> *"My husband cannot drink MAR water because of saltiness or salinity that is why I go to collect water from [neighbor's] house PSF."*

Regarding saltiness, one FGD participant stated, *"If we lift/abstract 4000 liters water per day and recharge/infiltrate 3000 liter, then MAR water will be saline."*

MAR water knowledge and use

To enhance MAR system management, understanding the level of knowledge and reasons for use/non-use were assessed among community respondents. Almost half (11) reported that they were familiar with MAR but don't understand how it works. However, one third (8/24) said they knew how it works. They mostly heard about MAR from their neighbors or from others in their locality/village. Only one reported that he heard about MAR through a meeting. Those who were motivated to use MAR water reported their understanding by stating:

> *"MAR is the source of fresh water. In this system fresh pond water and harvested rain water is infiltrated at the ground layer through a filtering process. Water is stored in a reserve tank. It has also a tubewell with this system. People can collect water by pumping the tubewell."*

> *"So far I know about MAR, it brings up water from underground by a machine and filters water with medicine then supply water comes through a tube well."*

> *"This water gets filtered in 3 steps. At first, water is filtered in the tank installed on the top. After that in the selection well where there is sand, water is again filtered there. Lastly, while water is pumped up, it is filtered again for the third time. There is less possibility of germs and bacteria to get inside (the MAR system.)"*

Lack of sufficient information about the MAR system and messages to encourage uptake were commonly cited barriers for MAR water use, identified by all the participants in all FGDs and by key informants. One key informant stated,

> *"We cannot expect sustainability without community mobilization. At first we need to make the community aware about MAR technology."*

Moreover, one FGD participants said; *"As we work at the MAR site, we know MAR water is safe because we have seen the test reports. But they did not deliver us any microbiological report to show the community. That's why community people do not want to believe what we say verbally. Once we can show the report to the community residents as evidence, they will believe that MAR water is safe."*

The majority (17/24) considered MAR water safe because they think there are no germs present. Nonetheless, respondents mentioned several problems including dissatisfaction with water quality (salinity/iron/smell/dirt in the water) that can act as barriers to uptake. Study respondents stated:

Former users said *"I used to collect water from there (MAR). But recently, I collect less from there as my husband doesn't like to drink water from this source. Other members do not wish to drink water from there as children urinate or defecate near the tank (of MAR).*

> *"Water is saline a little bit. We faced difficulties in digestion, abdominal discomfort and we suffered from diarrhea and nausea for drinking MAR water. So, people are not using it now."*

A current user said *"My sister-in-law never drinks MAR water. She never touches water of that pond. There is a toilet on the top of that cyclone center (where MAR is situated). The septic tank of that toilet is set on the edge of that pond. A few days ago…edges of that pond sank/broke, then the tank came outside. She thinks that feces from that tank go into that pond. That is why she doesn't drink water from that pond*

Some respondents described what they perceived as health advantages of drinking MAR water. One current user said;

"*My family members are not getting affected with diarrhea and cholera for the last 6 months after they had started drinking this water. This water is safe and good for health.*"

MAR system management

Almost half (10) of our community member respondents considered maintenance issues the primary concern for MAR technology sustainability. They suggested that to maintain this system, to manage payments and to maintain the quality of water, proper maintenance and oversight of MAR sites are needed. This may help to the increase the proportion of MAR water users. Moreover, respondents described the importance of the caretaker role. Respondents mentioned that improvement of water quality, water availability and proper maintenance is essential for sustainability. One respondent stated,

> *"Sustainability of this MAR technology depends on good maintenance and on responsible honest dedicated caretaker."*

A range of problems were described in collecting water, and some respondents found collecting water a positive experience. They stated:

A current user said *"Usually, I collect MAR water in the evening twice or thrice every day. MAR is located in the Madrasha (Islamic religion educational institution) area that is why it was not feasible for a woman to collect water from MAR at day time."*

A current user from a high salinity community said *"My previous water source was two hours walking distance."*

A current user said *"Usually I go to collect water from MAR in the morning, so I get water within 5 minutes. But the women go to collect more water from MAR in the evening, so they need to stand in a queue for a long time."*

A current user said *"We are all living here drink this water. Whenever we go to collect water we meet with each other and get an opportunity to greet each other. It is easy/good to stay united."*

However, regarding the limited water collection time, one FGD participant (MAR management supervisor/caretaker) stated that *"In some MAR sites, tap remains open to collect water all the time but in some other sites tap is opened two times in a day, like in the morning and in the evening. If we keep it open for the whole day; people, mostly children waste water."*

Respondents reported that the MAR system is maintained and managed by a user committee with a caretaker appointed to look after the site; daily system maintenance and operation. Users contribute a small sum of money every month towards maintaining the MAR system (for electricity bills and repairs), usually between USD 0.25 to USD 0.75. The payment is sometimes based on the financial ability of households. One respondent mentioned that,

“We, the users have formed a committee and appointed a caretaker to maintain this MAR site. He cleans the sack and repairs washers. Sometimes a daily laborer is hired to clean the sack/jute bag inside the filter.”

Individual respondents reported, *“My uncle is the president of the MAR committee. We don’t need to pay”; “We are not paying willingly. Previously we did not pay any money. If MAR provides water for the whole day then we will pay 20 taka (USD 0.25) willingly”;“It is affordable to spend 2 taka (USD 0.025) daily for drinking purposes for this kind of safe water source;”;“Payment should be fixed considering household’s financial ability. 20 taka is burden for poor people.”*

Some respondents reported that they paid for water prior to the MAR system installation. They said:

A current user said *“When water supply from MAR had not started, I used to pay 80 (USD 1) taka monthly for using PSF supply water. That was not affordable for me”*

Another current user said *“Sometimes when there is water scarcity then I have to bring water from a distant place by van and spend 60-100 taka for that. For 2 drums of MAR water (each drum contains almost 200 liter water) I have to pay 60-70 taka. During summer we need to carry water by van”*

Some of the users (4) were not paying for MAR use but they mentioned some of their demands and they told that they will be willing to pay in the future if those demands are fulfilled. Some of their demands were; if water quality improves and all the villagers agree to pay monthly USD 0.13 to USD 0.25, and if MAR water remains available the whole day; then they will be willing to pay for MAR water in future. One respondent stated,

“We are not paying willingly. Previously we did not pay any money. If MAR provides water for the whole day then we will pay (USD 0.25)20 taka willingly.”

In contrast, key informants (who oversee the MAR implementation) and focus group participants (MAR management supervisor/caretaker) thought that management and maintenance issues were their primary concern, which were impeded by limited funds, as users do not pay regularly. He said,

“Irregular payment of money creates problem in maintenance and management of MAR technology.”

Discussion

Communities in south-west coastal Bangladesh are vulnerable to the health impact of saline water consumption and cannot rely on ground water, ponds, or ad-hoc rainwater collection to meet their drinking water needs without involving technologies. Communities’ drinking water practices are explained by the contextual dimension at the community and individual level of the IBM-WASH framework (Table 3).

Table 3
Contextual, psychosocial and technological dimensions of the Integrated Behavioral Model for Water, Sanitation and Hygiene [24] for the MAR system, 2013.

Levels	Contextual	Psychosocial “Software”	Technology "hardware"
Structural/ MAR system	-Southwest coastal Bangladesh shallow tubewells provide ‘saline’* drinking water in the dry season. -People consume up to 16 gm sodium per day only through saline drinking groundwater; groundwater salinity due to climate change -MAR system is costly to install but a permanent structure.	-Initial introductory talks provided by MAR installation staff; some MAR systems have signs in place to describe the system, its use and maintenance.	-MAR systems infiltrate ‘fresh water’** into groundwater aquifers to provide low salinity drinking water -MAR systems were installed with funding from Unicef. Households use their own collection vessels. -The recurrent cost for MAR water usage to be obtained from households. -Care-taker maintains and operates the system on a daily basis and the technical supervisor visits the site once a week, continuously monitor the rate of infiltration and abstraction - Care-taker records the amount of water infiltration and abstraction every day, tests the MAR water turbidity daily and cleans the filter chamber once a month

*saline water = electrical conductivity (EC) > 700uS/cm, **freshwater = EC < 700uS/cm

Levels	Contextual	Psychosocial “Software”	Technology "hardware"
Community	-Pond water is low saline during wet season, used for drinking and cooking. Pond water is contaminated but some households treat this water -Rainwater used for drinking in wet season. -Rainwater collection has been encouraged as a salinity mitigation method -Shallow tubewell water perceived as low salinity, used for drinking - MAR water is encouraged for use in dry season as tubewell water is high saline and pond water can be high saline.	-User committee formed; functions include collecting maintenance costs, appointing caretaker and technical supervisor, responsible for community mobilization and financial assurance -Neighbors describe the MAR system and its use to those who did not attend introductory meetings -Sign boards at some MAR systems provide information on how the system works	-Project funds maintenance until MAR water meets standards for salinity, arsenic, iron and fecal coliforms. The site is then handed over to the User Committee -Household members draw water from MAR systems using a hand-pump, which is a familiar technology. Sometimes there are queues. -Community members that live more distant from MAR systems are less likely to use them. -MAR maintenance supervisor responsible to operate the system to recharge the aquifers to provide low saline drinking water in the dry season.
Interpersonal/ Household members and neighbors	- Users thought that MAR water quality is better than other drinking water sources. -Though having limited knowledge of the impact of drinking saline water on health, but perceived few visible effects related to drinking saline water. - Female is mainly responsible to manage water for household use, including drinking water.	-No active promotion of MAR water after the initial introductory meetings. No measures to enhance uptake such as a ‘refresher’ meeting to capture those who missed the first	-Some complained that the MAR system was locked at certain times. -Some complained that water quality was poor -Some actively avoid the peak water collection time and the queues

*saline water = electrical conductivity (EC) > 700uS/cm, **freshwater = EC < 700uS/cm

Levels	Contextual	Psychosocial “Software”	Technology "hardware"
Individual	-Some households in the MAR catchment area are low socioeconomic status [About two-third of the households (among study participants) earned up-to 10,000 taka per month; selected to represent these income ranges.]	-Information on water quality not provided to the community	-Pond water was considered low saline and was easy to obtain, close to households. -The recurrent cost for MAR water usage to be obtained from households. -MAR system caretaker is unpaid -MAR system caretaker/supervisor collect funds from households for MAR maintenance and operating costs. .
Behavioral/ Habitual	-During dry season, households typically used pond and shallow tubewell water for drinking and cooking before the MAR system was installed. -Some respondents reported that they used a method to treat pond water	-Household members perceived that treated pond water was safe.	-The MAR system was sometimes located at some distance from the household -Respondents reported concurrently using different water sources for different purposes and different sources by season
*saline water = electrical conductivity (EC) > 700uS/cm, **freshwater = EC < 700uS/cm			

The MAR systems were still functioning and being used by adjacent communities 6 years after installation. However, monthly funds that community members reported paying were extremely low and sometimes zero; insufficient to cover operation and maintenance costs. Funding is a major barrier to system sustainability and this concern was mentioned by MAR supervisory staff, with implications for sustained caretaker retainment.

MAR management related findings are explained by the contextual and psychosocial dimension at community/interpersonal level, and technological dimension at the community/individual level in the IBM-WASH framework (Table 3). Participants described community enthusiasm for MAR water and keenness to be committee members, the duties of which included collecting funds, at times covering fees for poorer households. Participants described the importance of community ownership. Ground water comes with no recurring costs, however, there are installment and occasional replacement costs [25], the initial drilling cost is usually met by households [5, 6, 26]. At times wells stop functioning and new ones need to be sunk. There is no recurring cost for pond water. Thus, people are not accustomed to paying for drinking water [26, 27]. Rainwater is considered readily available and to have no cost [28], but water storage vessels need to be provided by households thereby limiting collection capacity especially among

the poor [29, 30]. Low water tariffs have been described as a barrier to efficient water management in low income countries [31]. Further research is needed to explore mechanisms for equitably funding recurrent MAR system costs and potentially that of a permanent caretaker to enhance maintenance and in turn sustainability; this applies to any technology that is planned for salinity mitigation in Southwest coastal Bangladesh and low-middle income countries with similar interventions that include water and hardware management issues. Without a more robust funding mechanism, sustainability in the absence of project support is unlikely. Economic studies to determine funding mechanisms are warranted.

In this study, we found that none of the community members described a link between salinity and blood pressure, heart diseases, other circulatory diseases or adverse pregnancy outcomes. Increasing community health impact awareness has the potential of increasing the number of paying users. A further barrier was limited knowledge; only one third reported that they knew how the system works, and most heard about MAR from their neighbors or others from their locality/village, but not from a social behavioral change communication (SBCC) campaign. Encouraging MAR water uptake could benefit from SBCC and more compelling, potentially marketing-based promotional strategies. Our data suggest that there is a need to better inform the community about advantages of the system, the impact of salinity on human and animal. Messages on how the system works may decrease concerns about water quality, particularly allaying fears about using water from ponds that are contaminated with human and animal excreta. Promotion should include informing the community that the system is resistant to contamination during storms (runoff) and tidal surges (runoff plus salinity), the volume of water that households can collect each day to allay fears of running short. Water taste was found important, similarly elsewhere in Bangladesh [32], thus acknowledging low saline water taste in addition to health benefits could enhance uptake. More compelling SBCC delivery could include displaying messages at MAR sites, rotating the messages to maximize impact or promoting water collection as a social occasion [32].

Community members stated different barriers related to MAR water use/collection, including limited timing to collect water and location of MAR site. Convenience is important for water technology acceptance, as found among other communities in Bangladesh [32]. Thus, solving issues related to inconvenience or providing compelling reasons for the inconvenience are important to consider. Financial incentives may help. Lower acceptability of water from a shared source has been described [32], however individual user systems can also fail. When a concrete bio-sand filter was provided to individual households in the Dominican Republic, 10% of households were no longer using filtered water one year after installation [33].

Water systems that require continuous operation and maintenance are rarely sustained by local communities in the post-project period when logistical and/or financial support end [33–35], and when technical issues are encountered [36]. Strengthening management and maintenance of MAR system could optimize its water use. Methods to enhance community maintenance of water systems after project staff exit can be applied elsewhere.

Limitations to the study include collection of data among a small number of participants. However, to maximize variability in participants and hence their responses, we selected sites from across the three districts where MAR systems were implemented and included sites across aquifer salinity levels. The field team enrolled different types of households based on distance from the MAR system and user category. We also tried to ensure variation across household economic status. Because our study participants had similar practices, along with similar perceptions about the MAR system and water, our findings from this formative study provide a foundation to enhance management systems, which could be applicable for similar settings and other engineering-based water treatment and distribution technologies.

In summary, the concerns about management related to finance, in addition to the amount collected are the greatest threat to system functionality and sustainability. There seemed to be a wide range of payment methods and costs; consistency and equity are important. Additionally, many were concerned about the way in which funds were being managed. It is critical that a committee has guidelines on how to spend the collected sums and to convey transparency to the community members. Developing a simple governance guide for committees to follow would be ideal. Management/user committee can encourage technology uptake, monitor quality, keep the system operational and recover costs.

Declarations

Ethics approval and consent to participate

Data collectors explained the research study objectives clearly to study participants reading the content of consent forms. Before taking part in the study, these participants provided written informed consent which was documented by a signature. The protocol for this study was reviewed and approved by the icddr,b Institutional Review Board, protocol number PR-15096.

Consent for publication: The authors gave their consent for publication of this original research work.

Availability of data and material: The authors ensure the availability of data and material of this research work and readers can access the data upon request.

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Authors' contributions

FAN developed the related qualitative part of the research protocol and all authors provided input in its design and methodological development. FAN developed the data collection instruments. LU provided conceptual guidance for data analysis and manuscript development. AS and TJ collects/supervises the data collection, analyzed and summarized the data. FAN drafted the initial manuscript and all authors commented on the drafts and approved the final manuscript. MAN and MR conceptualized the study and secured the funding.

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Competing interests

The authors declare that they have no competing interests.

References

1. **Underground fresh water storage. A practical solution to increase water security in saline deltas.** [http://www.gwp.org/contentassets/396c023d522441c28b57113134617854/underground-fresh-water-storage—a-practical-solution-to-increase-water-security-in-saline-deltas.pdf]
2. Cutler JA, Follmann D, Allender PS: **Randomized trials of sodium reduction: an overview**. *Am J Clin Nutr* 1997, **65**(2 Suppl):643S-651S.
3. Ercumen A, Naser AM, Unicomb L, Arnold BF, Colford Jr JM, Luby SP: **Effects of Source- versus Household Contamination of Tubewell Water on Child Diarrhea in Rural Bangladesh: A Randomized Controlled Trial**. *PLOS ONE* 2015, **10**(3):e0121907.
4. Lam Y, Surkan P, Winch P, Nizame F: **Freshwater access in high salinity regions: impacts and adaptation insights from the Ganges River Delta**. *J Glob Health Rep* 2018, **2018;2: e2018007**.
5. Islam A, Sakakibara H, Karim R, Sekine M: **Potable water scarcity: options and issues in the coastal areas of Bangladesh**. *J Water Health* 2013, **11**(3):532-542.
6. Sultana S, Ahmed K, Mahtab-Ul-Alam S, Hasan M, Tuinhof A, S G: **Low-Cost Aquifer Storage and Recovery: Implications for Improving Drinking Water Access for Rural Communities in Coastal Bangladesh**. *Journal of Hydrologic Engineering* 2014.
7. Mozaffarian D, Fahimi S, Singh GM, Micha R, Khatibzadeh S, Engell RE, Lim S, Danaei G, Ezzati M, Powles J *et al*: **Global sodium consumption and death from cardiovascular causes**. *N Engl J Med* 2014, **371**(7):624-634.
8. Talukder MRR, Rutherford S, Phung D, Islam MZ, Chu C: **The effect of drinking water salinity on blood pressure in young adults of coastal Bangladesh**. *Environ Pollut* 2016, **214**:248-254.
9. Khan AE, Scheelbeek PF, Shilpi AB, Chan Q, Mojumder SK, Rahman A, Haines A, Vineis P: **Salinity in drinking water and the risk of (pre)eclampsia and gestational hypertension in coastal Bangladesh: a case-control study**. *PLoS One* 2014, **9**(9):e108715.
10. Rao CR, Kamath VG, Shetty A, Kamath A: **High blood pressure prevalence and significant correlates: a quantitative analysis from coastal karnataka, India**. *ISRN Prev Med* 2013, **2013**:574973.

11. Chen X, Wei W, Zou S, Wu X, Zhou B, Fu L, Wang H, Shi J: **Trends in the prevalence of hypertension in island and coastal areas of china: a systematic review with meta-analysis**. *Am J Hypertens* 2014, **27**(12):1503-1510.
12. Reddy V, Jacob G, Ballala K, Ravi C, Ravi B, Gandhi P: **A Study on the Prevalence of Hypertension Among Young Adults in a Coastal District of Karnataka, South India**. *International Journal of Healthcare and Biomedical Research* 2015, **2015;3(3):32-9**.
13. Strazzullo P, D'Elia L, Kandala N-B, Cappuccio FP: **Salt intake, stroke, and cardiovascular disease: meta-analysis of prospective studies**. *Bmj* 2009, **339**.
14. Sobsey MD, Stauber CE, Casanova LM, Brown JM, Elliott MA: **Point of use household drinking water filtration: A practical, effective solution for providing sustained access to safe drinking water in the developing world**. *Environmental science & technology* 2008, **42**(12):4261-4267.
15. Clasen TF: **Scaling Up Household Water Treatment among Low-Income Populations**. In. Geneva, Switzerland: World Health Organization; 2009.
16. Kabir AHME, Chakraborty TK, Ghosh GC: **Bio-Sand Filter (BSF): A Simple Water Treatment Device for Safe Drinking Water Supply and to Promote Health in Hazard Prone Hard-to-Reach Coastal Areas of Bangladesh**. *American Journal of Environmental Protection* 2016, **5**(5):109-114.
17. Conroy RM, Meegan ME, Joyce T, McGuigan K, J B: **Solar disinfection of water reduces diarrhoeal disease: an update**. *Arch Dis Child* 1999, **81**:337–338.
18. Collaborators GBDRF, Forouzanfar MH, Alexander L, Anderson HR, Bachman VF, Biryukov S, Brauer M, Burnett R, Casey D, Coates MM *et al*: **Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks in 188 countries, 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013**. *Lancet* 2015, **386**(10010):2287-2323.
19. G GF, Gleeson T: **Vulnerability of coastal aquifers to groundwater use and climate change**. *Nature Climate Change* 2012, **2012;2(5):342-5**.
20. Naser AM, Unicomb L, Doza S, Ahmed KM, Rahman M, Uddin MN, Quraishi SB, Selim S, Shamsudduha M, Burgess W *et al*: **Stepped-wedge cluster-randomised controlled trial to assess the cardiovascular health effects of a managed aquifer recharge initiative to reduce drinking water salinity in southwest coastal Bangladesh: study design and rationale**. *BMJ Open* 2017, **7**(9):e015205.
21. Nizame FA, Leontsini E, Luby SP, Nuruzzaman M, Parveen S, Winch PJ, Ram PK, Unicomb L: **Hygiene Practices During Food Preparation in Rural Bangladesh: Opportunities to Improve the Impact of Handwashing Interventions**. *Am J Trop Med Hyg* 2016, **95**(2):288-297.
22. Nizame FA, Unicomb L, Sanghvi T, Roy S, Nuruzzaman M, Ghosh PK, Winch PJ, Luby SP: **Handwashing before food preparation and child feeding: a missed opportunity for hygiene promotion**. *Am J Trop Med Hyg* 2013, **89**(6):1179-1185.
23. Hussain F, Clasen T, Akter S, Bawel V, Luby SP, Leontsini E, Unicomb L, Barua MK, Thomas B, Winch PJ: **Advantages and limitations for users of double pit pour-flush latrines: a qualitative study in rural**

Bangladesh. *BMC public health* 2017, **17**(1):515.

24. Dreibelbis R, Winch PJ, Leontsini E, Hulland KR, Ram PK, Unicomb L, Luby SP: **The Integrated Behavioural Model for Water, Sanitation, and Hygiene: a systematic review of behavioural models and a framework for designing and evaluating behaviour change interventions in infrastructure-restricted settings**. *BMC public health* 2013, **13**:1015.
25. Naggar DOM: **ANALYSIS OF GROUNDWATER PRODUCTION COST** *Seventh International Water Technology Conference Cairo 1-3 April 2003* 2003.
26. Qureshi AS, Ahmed Z, Krupnik TJ: **Groundwater Management in Bangladesh: an Analysis of Problems and Opportunities**. In.: Cereal Systems Initiative for South Asia Mechanization and Irrigation (CSISA-MI) Project, Research Report No. 2. International Maize and Wheat Improvement Centre CIMMYT: Dhaka, Bangladesh; 2014.
27. Dey NC, Parvez M, Saha R, Islam MR, Akter T, Rahman M, Barua M: **Water Quality and Willingness to Pay for Safe Drinking Water in Tala Upazila in a Coastal District of Bangladesh**. *Expo Health* 2018:1-14.
28. Gupta SK, Islam MS, Johnston R, Ram PK, Luby SP: **The chulli water purifier: acceptability and effectiveness of an innovative strategy for household water treatment in Bangladesh**. *Am J Trop Med Hyg* 2008, **78**(6):979-984.
29. Ferdausi SA, Bolkland MW: **Rainwater harvesting for application in rural Bangladesh**. *26 WEDC Conference, Dhaka, Bangladesh* 2000.
30. Islam KZ, Islam MS, Lacoursière JO, Dessborn L: **Low Cost Rainwater Harvesting: An Alternate Solution to Salinity Affected Coastal Region of Bangladesh**. *American Journal of Water Resources* 2014, **Vol. 2** (6):141-148.
31. Whittington D: **Municipal water pricing and tariff design: a reform agenda for South Asia** *Water Policy* 2003, **5 (2003) 61–76**.
32. Inauen J, Hossain MM, Johnston RB, Mosler HJ: **Acceptance and use of eight arsenic-safe drinking water options in Bangladesh**. *PLoS One* 2013, **8**(1):e53640.
33. Aiken BA, Stauber CE, Ortiz GM, Sobsey MD: **An assessment of continued use and health impact of the concrete biosand filter in Bonao, Dominican Republic**. *Am J Trop Med Hyg* 2011, **85**(2):309-317.
34. Casanova LM, Walters A, Naghawatte A, Sobsey MD: **Factors affecting continued use of ceramic water purifiers distributed to tsunami-affected communities in Sri Lanka**. *Trop Med Int Health* 2012, **17**(11):1361-1368.
35. Hulland K, Martin N, Dreibelbis R, J JDV, Winch P: **What factors affect sustained adoption of safe water, hygiene and sanitation technologies? A systematic review of literature**. *London: EPPI-Centre, Social Science Research Unit, UCL Institute of Education, University College London* 2015, **ISBN: 978-1-907345-77-7**.
36. Martin R, ed. : **Clogging issues associated with managed aquifer recharge methods. IAH Commission on Managing Aquifer Recharge. (www.iah.org/recharge/clogging.htm)**; 2013.