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WASH Field Note FN/13/2018

Managed Aquifer Recharge (MAR): Protecting Communities from Saline Intrusion of Groundwater in Costal Areas of Bangladesh

SUMMARY

- Climate change is leading to rising sea levels and more extreme weather events, which can destroy WASH facilities and lead to saline intrusion of coastal fresh water aquifers.
- In coastal areas of Bangladesh, approximately 20 million people are exposed to the threats of increasing salt water intrusion into surface and ground water sources.
- In response to the crisis, UNICEF and partners have piloted and scaled-up Managed Aquifer Recharge (MAR), a technique which collects and treats water from ponds and roofs (rainwater) and injects it underground for storage and future use.
- Each MAR system can serve hundreds of people and can be maintained by the communities themselves with periodic external support.
- This scaleable resilient technology option is an ideal solution for creating sustainable access to safe water in costal communities affected by climate change.

Introduction

Rising sea levels, combined with the increased frequency and intensity of extreme weather events such as cyclones, have doubled the number of storm surge events in the twentieth century, a trend that is set to continue. Storm surges can lead to the destruction of crucial water and sanitation infrastructure and saltwater intrusion into groundwater sources.

Saltwater intrusion is a result of vertical and lateral invasion of seawater into coastal aquifers. When freshwater and saltwater are mixed, brackish water is created. Saltwater intrusion affects both the quality and quantity of freshwater resources, making water unsafe for human consumption and threatening livelihoods, public health, agriculture, aquaculture, infrastructure and coastal ecosystems.

Bangladesh is one of the countries worst affected by saltwater intrusion into groundwater. Between 1973 and 2009, the salinity affected area increased from 8,330 square km, to 10,560 km, with approximately 20 million people being affected. The increased salinity also has maternal and child health implications. Women in southwest coastal areas have a higher prevalence of gestational hypertension compared to women in other areas.

The country's low topography makes 60% of its land surface vulnerable to frequent flooding and its location along the Bay of Bengal makes it prone to cyclonic storms. The resulting destruction and contamination of water supplies further aggravates water quality and sustainability challenges.

Although 97.8% of the population have access to improved water sources, only 35% of the population have access to drinking water sources free from chemical and microbial contamination.

Twenty-five per cent of the population live in coastal areas and are highly vulnerable to the impacts of saline intrusion, water scarcity and the destruction of WASH infrastructure caused by extreme weather events such as cyclones.

To address these issues, UNICEF, in collaboration with Departhment of Public Health Engineering, Dhaka University and Acacia Water (Netherlands), have introduced and scaled up MAR implementation in three coastal districts (Khulna, Satkhira, Bagherat) of Khulna Division since 2009. Seven local NGO partners were engaged to facilitate community based activities.

KEY POINTS

- *MAR is being implemented at scale in Bangladesh; 100 systems have been installed so far.*
- *The systems, which store freshwater in the ground, can help provide resilience against the impacts of cyclonic surges, providing safe water when other traditional sources have been damaged by floods.*
- *The average estimated cost of a combined pond and rainwater infiltration system is BDT 600,000 (US$ 7,760) of which, approximately half relates to the cost of physical construction and the remainder, is spent on designing, supervising and monitoring.*
- *The MAR system has the potential to be used throughout Bangladesh and in low-lying areas around the world to improve WASH climate resilience in the most vulnerable communities.*

Description of Intervention

1. The technology

Although MAR is not a new concept for water storage, it is the first time it has being used in Bangladesh to recharge and abstract drinking water as a rural water supply option.

Rain (collected from roof tops) or water from freshwater ponds is collected, transported through pipes, passed through a sand filter to reduce turbidity and injected underground into the shallow saline aquifer through a ring of infiltration wells. This then creates a "bubble" of freshwater which is abstracted using a hand pump. Each MAR system can provide drinking water for several hundred people.

2. Application of the technology to the Bangladesh context

The inhabitants of the coastal area of Bangladesh face significant challenge in terms of quality, quantity and year-round availability of drinking water. This is because in the outer coastal zone both the shallow and deep aquifers are saline over much of the area, with high concentrations of arsenic and iron in some areas. The shallow aquifer is mostly brackish with fresh water available only as discrete lenses at shallow depths and limited in geographical extent

Most deep aquifers in the area are saline. In a few areas, where the deeper aquifer water is relatively fresh, tubewells (more than 150 m in depth) have been constructed. Surface water supply is diffuclut as a drinking water source without treatment for microbial contamination. Furthermore, surface water sources are at risk of cyclonic surge.

Traditionally rural communities collect rain water for drinking and cooking during the monsoon season (May to September) and in the dry season pond water is used. Some agencies have introduced other options, such as reverse osmosis, in a non-coordinated manner. However, water reserves in the ponds are increasingly being threatened by inundation caused by storm surges.

3. Site Selection

The coastal aquifer system in Bangladesh is hydrogeologically very heterogeneous, with significant changes in aquifer sediment evident within short vertical and horizontal distances.

The target storage zone for the MAR pilot sites was a shallow brackish aquifer which is composed of unconsolidated fine to medium grained sand, occasionally inter bedded with silty clays with a static water level from 1 to 2.5 m below the ground surface.

The MAR project commenced in 2009 with a mapping exercise to identify the potential technically feasible and most vulenrable areas.

A series of GIS maps were generated using various parameters including water quality (arsenic, iron, manganese and conductivity) and the occurrence of surface water and groundwater levels to highlight areas with acute water quality and quantity problems.

The distribution of areas with poor water quality, deep water tables (more than 7.5m), which were more than 1km from perennial rivers, and areas with saline shallow groundwater were then collated and overlaid to best define the target areas.

For the preliminary investigations, it was decided to prioritise three districts along the coastal belt in Khulna, Bagerhat and Satkhira. To determine the actual pilot sites within the three districts, detailed mapping (at a union level) using village-level information on water use, and the number and type of existing water sources (including deep tubewells, shallow tubewells, ponds, pond sand filters and rain water harvesting systems) was carried out. Data on the existing water types and population density was then collated to identify the villages with the highest levels of water scarcity.

4. Construction of MAR sites

For the selected MAR sites, two different technological options were implemented, depending upon the ground conditions and availability of space, these were:

1. Over ground (surface) recharge system
2. Underground chamber recharge system (where there is limited space).

Depending upon the technological option, different components are used. Schematic diagrams of these options are shown in Fig.1.

For the infiltration wells, there are three main components:

a. Filter screen (locally designed and made, comprising a mild steel rod frame wrapped in chicken mesh, varying in diameter from 8 to 18 inches), providing a less expensive and more sustainable option than PVC and stainless steel alternatives
b. Casing pipe
c. Gravel

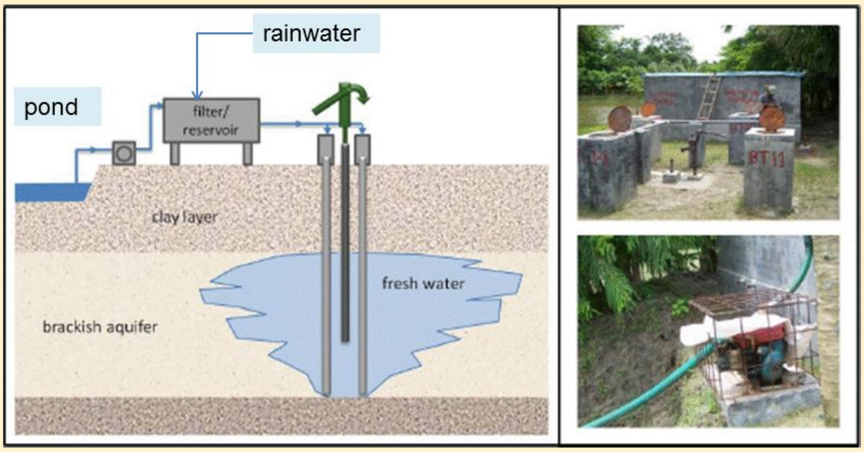
5. Costs

The average estimated cost of a combined pond and rainwater infiltration system is approximately BDT

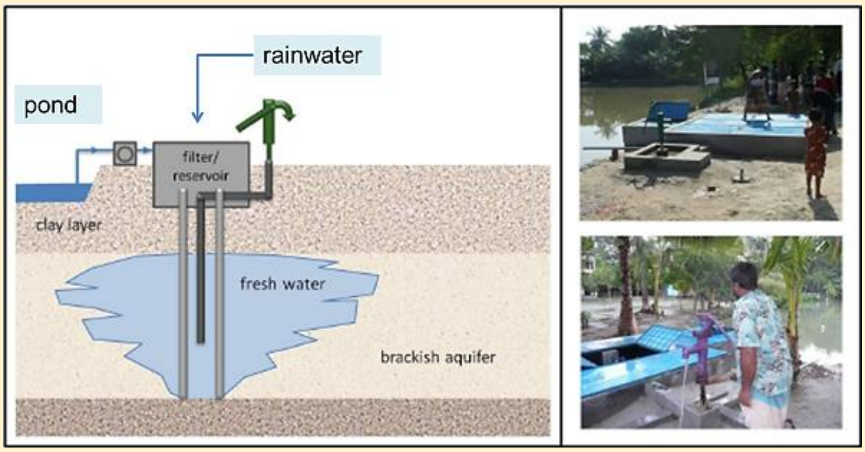
600,000 (US$ 7,760) of which approximately half relates to the cost of physical construction and the remainder, is spent on designing, supervising and monitoring. The costs are reduced to about US$ 2,500 when abandoned Pond Sand Filters are integrated to the system. The cost effectiveness of MAR is enhanced by the use of materials that are locally available. Compared to other climate resilient water systems, MAR is highly cost effective.

Fig.1 The Managed Aquifer Recharge System

Option 1: Over ground (surface) recharge system option

Schematic	Technologies/infrastructure
	• A recharge shaft; • An infiltration reservoir (divided into 2 chambers – one for filtration of the pond water and another one for storing filtered water prior to infiltration) • Observation wells (4 to 5) • Infiltration wells (4 or 6 infiltration wells of different diameter).

Option 2: Underground chamber recharge system

Schematic	Technologies/infrastructure
	• Sub-surface infiltration chamber (divided into 2 chambers – one for filtration5 of the pond water and another one for storing filtered water prior to infiltration); • Observation wells (4 to 5); • Infiltration well (mostly directly below the tank).

6. Testing of the MAR sites

Various steps were taken to determine the technical and social applicability of the MAR schemes:

i. *Technical feasibility and performance assessment:*

- Regular water quality testing (EC, turbidity, arsenic, iron, *E.* coli) and determination of recovery infiltration and abstraction rate in all the sites.
- The results were shared with partners and used to determine trends and to identify issues for review.

ii. *Social feasibility and user perception surveys:*

- Knowledge, Attitude and Practice and Social Assessment Surveys
- Operational testing of context-specific operation and maintenance (O&M) models.
  - Members were trained on O&M, Water Safety Planning (WSP) and a phased mentoring and handing over approach was utilised to ensure the long-term sustainable management of sites.
  - Community based operation and maintenance was essenital to ensure that the filters are working effectively and to reduce clogging, which can be a challenge for well injection systems.

Clogging management: a) washing the Geojute cover of the sand filtration chamber b) backwashing of gravel pack of infiltration wells, c) manual washing of gravel pack of infiltration well, and d) difference of gravel before and after washing.

iii. Community ownership

- To ensure community ownership, communities were engaged in discussions about the context specific feasibility, siting and willingness to pay.

iv. *Facilitating a sustainable scale-up strategy*:

- Partntership with Government (DPHE) partners during all the phases of the project.
- Policy review, advocacy and capacity building of government partners to facilitate inclusion of MAR in policy documents and to leverage commitment for the construction of a further 100 MAR sites[1].
- Development of sustainability tools (social marketing and capacity building and decision making criteria).

Following the testing, of various options the most effective management models were found to be:

1. Managed by community with support from local institutions.
2. Managed by local institution, e.g. school or hospital with involvement of the local community.

OUTCOMES

- Sixty-six of the 100 of the MAR systems are fully operational and being maintained by communities providing safe water access to 26,800 people.
- User perception data on MAR is now available to the sector in the form of social assessments and a KAP survey.
- A solid evidence base has now been generated to demonstrate the technical feasibility of MAR as a rural water supply option in coastal areas (including data on arsenic, iron, turbidity, salinity, electro– conductivity and E.coli) from 2009 – 2018
- Tools for scaling up and enhancing sustainability have been developed and introduced to key stakeholders at community, local government and national levels:
    - Water Safety Plans (75 sites) and site specific management plans have been developed (52 sites).

[1] The Swedish International Development Agency is supporting the points 1-3 as well as Piloting MAR in urban and drought prone areas.

- Sixty-six User Committee Groups have been established to manage the operation and maintenance of the MAR systems.
- A social marketing strategy has been developed and tested at selected sites.
- Research has shown that MAR leads to an improvement in health, through a reduction in hypertension.

- MAR is now included in the Government of Bangladesh's National Sustainable Development Goal 6.1 Action Plan.

CHALLENGES

- Thirty four of the 100 MAR sites are not functional due to a mix of social, technical and institutional issues. All these sites provide important lessons which are documented to assist future development of MAR in Bangladesh and other interested countries.
- The willignness of communities to make payments and to operate and maintain MAR during the monsoon season when rainwater is readily available. This results in insufficient water quantity and poor water quality during the dry season.
- It takes a at least one full monsoon season to operationalize MAR - for sufficient infiltration before water can be extracted.
- Competing demand for pond use for shrimp cultivation.
- Fluctuations in arsenic concentrations in the water.
- Inadequate oversight by government at local level following project handover due to Government policy of handing over all rural water supply projects to communities.
- Unrealistic expectations of the community caretaker to operate and maintain the system on a volunteerism basis.
- Absence of integrated water supply planning resulting in the duplication of water supply options in same locality e.g. Reverse Osmosis located next to MAR.

LESSONS LEARNED

- There are strong linkages between the social, technical and financial aspects of MAR, which must be considered to faciliate sucessful responses to the challenges.
- MAR can reduce ambient conductivity to acceptable drinking water limits (<2.0 mS/cm) if initial source water concentrations are less than 10,000 mS/cm.
- MAR can reduce arsenic concentraions to within the GoB drinking water standards if the ambient concentration of the source water is below 100ppb.
- A remunerated caretaker is essential for ensuring the sustainability of systems.
- MAR is context specific and more sustainable when sited where there are no alternative safe drinking water sources.
- Institutional support from government for water quality monitoring and surveillance, periodic maintenance is critical to ensure the continued production of safe water.
- Power outages are common and so alternative designs need to be investigated which include gravity or the use of solar power.
- MAR is a disaster resilient option and should be showcased to the Ministry of Disaster Management and Minsistry of Environment and Forestry for inclusion in government plans as a water supply option.

CONCLUSION

MAR has been successfully piloted and scaled-up in Bangladesh, providing safe water to 26,800 people in coastal regions. The systems have the potential to be used throughout Bangladesh and globally in low-lying areas affected by saline intrusion, rising sea levels and storm surges, to safeguard water supply and climate resilience.

The technical and social feasibility of MAR as a climate resilient, rural water supply option has clearly been demonstrated. However, critical gaps in national policy remain, including the payment of system caretakers, which is undermining the post-installation sustainability of the systems.

Integrated water supply planning is also vital to avoid duplication and ensure the needs of the poorest and most vulnerable are prioritized.

The inclusion of solar pumping options within the system would help to improve climate resilience and environmental sustainability in the long-term.

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CREDITS

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