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SUSTAINING REVERSE OSMOSIS WATER TREATMENT SYSTEMS: An Example From Bangladesh

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ABSTRACT

The United States Agency for International Development (USAID) Bureau for Humanitarian Assistance (BHA)-funded Resilience Food Security Activity (RFSA) Nobo Jatra (New Beginning), implemented by World Vision in southwest Bangladesh, installed ten reverse osmosis (RO) water treatment plants in areas where groundwater salinity, seawater incursion, and other factors were preventing communities from accessing safe and reliable domestic water supplies. RO technology requires relatively complex arrangements for operations and maintenance (O&M) to ensure continuous and reliable supplies. Nobo Jatra was able to achieve high levels of reliability and community satisfaction through a combination of innovative measures that addressed the technological, financial, and management aspects of RO plant operation. As a result, all ten RO plants continue to function, providing communities with safe drinking water all year round.

INTRODUCTION

Water, sanitation and hygiene (WASH) infrastructure includes physical assets such as wells, pumps, latrines, pipes, and treatment plants. This infrastructure is essential for basic human health and well-being, yet its provision remains a challenge in many parts of the world today. Building or installing WASH infrastructure is only a part

(above photo: Nobo Jatra)

of the challenge; equally important are the routine functions such as regular maintenance, repairs, checks, and adjustments that keep the infrastructure functioning and the financial, human, and institutional resources needed to enable and support these requirements. Collectively, these routine functions and supporting systems are called operations and maintenance (O&M).

Without O&M, all infrastructure eventually fails. Research indicates that around thirty percent of WASH infrastructure in developing countries fails after only a few years,[1] which represents a huge loss of value. It is estimated that value increases three- to fivefold when a suitable O&M program is implemented,[2] making it a highly cost-effective investment.

Unfortunately, there is no single, standard approach to O&M, since costs, responsibilities, spare parts, skills, accountability frameworks, and technical requirements all depend on the type of infrastructure and its operational context. A set of O&M arrangements that works well in one place may fail in another, even where the physical infrastructure asset is similar. However, there are overarching principles and approaches to O&M that are common across different environments and types of WASH infrastructure. Many of these principles seem surprisingly basic, such as ensuring that the right expertise is available to carry out repairs, or making sure that there is enough money to pay for O&M. Yet these principles are often frustratingly complex to implement.

As a result, the WASH community is always interested in O&M success stories—those instances where engineering and O&M design factors align to produce sustainable and resilient WASH infrastructure that appropriately and affordably serves the communities where it is installed. The implementation of sustainable reverse osmosis (RO) water treatment plants in southwest Bangladesh is such a success story. The purpose of this learning note is to tell this story and to share some of the general principles that appear to be foundational to its success with other Bureau for Humanitarian Assistance (BHA) partners to assist them with future projects.

WHAT IS REVERSE OSMOSIS?

In some places, water is too saline or too polluted to drink and difficult or impossible to treat using conventional filters or other traditional water treatment technology. This can lead to great hardships as community members struggle to find suitably fresh or unpolluted water. In southwest Bangladesh where Nobo Jatra works, low-lying land leads to salty estuarine water that pollutes drinking water in many places.

Reverse Osmosis (RO) is a way of removing dissolved salts and other dissolved or suspended unwanted constituents in saline or polluted water. RO works by exerting high pressure across a special semipermeable membrane to separate pure water (H2O) from the unwanted constituents. RO is especially useful where the only available water is brackish or saline, since dissolved salts such as sodium, potassium, and chloride are difficult to remove by other means.

RO is a useful technology that is often the only practical way of purifying saline water or water contaminated with other hard-to-remove constituents such as nitrate. However, RO can involve complex processes and machinery, and RO plants producing water for communities usually require both sophisticated O&M expertise and personnel soft skills to keep them running reliably. For example, RO plants are relatively energy intensive and need a reliable power supply. They also require specific kinds of maintenance—for example, the special membranes (often in the form of cartridges) need to be changed regularly. RO plants usually have a prefiltration stage so that suspended

1 H. Lockwood, "Sustaining Rural Water: A Comparative Study of Maintenance Models for Community-Managed Schemes," 2019, USAID / Sustainable WASH Systems.

2 J. Whinnery, "A Well Construction Cost-Benefit Analysis (CBA): For Water Supply Well Guidelines for use in Developing Countries," October 5, 2012, unpublished report, Oregon State University.

particles and other larger constituents of the raw water are removed before they can contact the delicate semipermeable membranes. These prefilters need to be cleaned and maintained; the purified water must be monitored for volume and quality, and the waste stream from RO plants must also be disposed of safely. RO plants also need an assured supply of raw water. Finally, a reliable supply of spare parts is critical to avoid outages and unreliable operation.

Any project considering an RO plant as part of a developmental strategy must first consider the characteristics and requirements of RO plant operation and design an appropriate O&M strategy, including considerations of financial sustainability. Just as importantly, RO plants also require access to products and supplies via a market.

FIGURE 1. An RO plant in Bangladesh *(photo: Nobo Jatra)*

The RO technology is managed by trained plant caretakers on a day to day basis. Water Management Committee members are also trained on operation and maintenance and support plant caretakers to ensure that the technology functions smoothly.

THE USAID BHA-FUNDED RESILIENCE FOOD SECURITY ACTIVITY NOBO JATRA

Nobo Jatra is a seven-year (2015–22) USAID BHA-funded Resilience Food Security Activity (RFSA) implemented by World Vision in Bangladesh.[3] Nobo Jatra means "new beginning" in Bangla, and the project concentrates on four *upazilas* (subdistricts) in southwest Bangladesh. Nobo Jatra is implemented in partnership with the Government of Bangladesh and Winrock International. One prime focus of Nobo Jatra is on sustained access to safe WASH services, including installation and rehabilitation of water supply facilities for vulnerable communities. Another key focus of Nobo Jatra is on strengthening disaster preparedness and reducing the risks associated with natural disasters. Where possible, Nobo Jatra introduced fee-based, locally owned models for safe water, which aligned with the project's sustainability objectives. To strengthen ownership and accountability, Nobo Jatra also built partnerships with various government entities, academia, community-based organizations, and service providers. In consultation with local communities, government, and the Department of Public Health Engineering (DPHE; the government body responsible for water services), Nobo Jatra has installed 3,319 water options, repaired 341 of these options, and supported the functionality of 643 water and sanitation committees. This has resulted

3 Nobo Jatra was initially awarded as a 5-year project from 2015–20 by USAID's BHA. A two-year sustainability anchored cost extension was awarded, running until September 2022. During the cost extension period, Nobo Jatra is focusing on system strengthening, transition, and handover to local communities, government, and the private sector where relevant.

in 148,066 households gaining access to basic drinking water. Nobo Jatra has also reached 487,629 people with WASH social and behavior change messaging on BabyWASH,[4] including information on hand washing with soap, safe drinking water, water treatment, and waste and fecal management.

In southwest Bangladesh where Nobo Jatra works, the low-lying land means that salty estuarine water pollutes drinking water in many places. Groundwater is affected by saline water intrusion, and surface water ponds, tanks, and other impoundments are vulnerable to seawater incursions. Storms in the Bay of Bengal and the Andaman Sea can cause storm surges that overtop coastal defenses and wreak havoc with water infrastructure. For example, both Cyclone Bulbul in November 2019 and Cyclone Amphan in May 2020 caused heavy rains and a severe storm surge over parts of Nobo Jatra's project area, in the process destroying thousands of homes and impacting power and water supplies. Rising average sea levels due to anthropogenic climate change place further pressure on infrastructure.

To deal with problems of persistent salinity and other contaminants, such as iron and arsenic, in community water supplies, Nobo Jatra opted to make use of RO technology in areas where other options were scarce. Nobo Jatra assessed the technology requirements and the O&M implications, combining these with the project's deep knowledge of the project areas and their social and economic characteristics.

NOBO JATRA'S EXPERIENCE WITH REVERSE OSMOSIS

Following USAID's collaborating, learning, and adapting framework, Nobo Jatra began by incrementally assessing the factors that have previously influenced the successes and failures of RO plants in the project areas. Existing RO plants in the four project upazilas were studied using key informant interviews, literature reviews, and field-based learning. Informants included RO plant caretakers, local DPHE officials, local government structures, and Water Management Committee (WMC) members. Nobo Jatra realized that the financial sustainability of the RO plants was a critical consideration, since previous initiatives that had initially succeeded were too often threatened in the long run by lack of an assured funding stream. The limited involvement of communities in daily governance and management of previous RO plants was a major gap; when NGO involvement ceased, the RO plants tended to stop functioning. In this way, large investments made in the past in RO technology were often disappointing. Clearly, a basic requirement was a robust business plan that provided value and satisfaction to consumers, while also ensuring that long-term O&M could be afforded and would be implemented. Nobo Jatra determined that if the financial sustainability of the envisaged RO plants was to be taken seriously, a fee-based water service model would be required. Nobo Jatra-designed RO plants have the capacity to produce 1,000 liters of treated water per hour and require an investment of approximately US$26,000 per plant, including all mechanical and civil structures.

However, charging users fees for water is easier said than done in southwest Bangladesh, where people have traditionally been reluctant to pay for water that is drawn from tube wells, ponds, or tanks. Nobo Jatra knew that they would need to change people's outlook on paying for water. Based on past experience, communities can be reluctant to pay for water when a safe water supply is not consistently provided throughout the year, or when there are prolonged repair delays that impede water service delivery. However, if the installation and management of water systems is collaborative from the design stage—involving communities, DPHE, and the local government—with a clear business operation model attuned to local context, Nobo Jatra was confident that people would be willing to pay for the safety, health, and convenience of purified water if it could be consistently and reliably delivered. Community-level social and behavior change messaging was also critical to shift mindsets

4 BabyWASH is an initiative that aims to integrate WASH into maternal, newborn and child health and early childhood development and nutrition, to have a more profound impact on child health outcomes in the first 1,000 days of life. Key interventions focus on hotspots in the first 1,000 days, including pregnancy, delivery, the first month of life, the onset of complementary feeding, and the onset of a child's mobility.

on paying for water and using the RO system rather than traditional water systems, such as deep tube wells, pond sand filters, or rain water harvesting systems (which can cease to function depending on the season). For the supply to be consistently reliable and of good quality, effective day-to-day management of the RO plants would be needed. To accomplish this, two key institutional structures were required—RO plant caretakers and WMCs.

Day-to-day O&M, repairs, water sales, and regular reporting are handled by the RO plant caretaker, a salaried full-time position. This includes monthly replacement of the polypropylene filter and annual replacement of the RO membrane filter. The caretaker's educational background and technical skill are important since the RO equipment requires particular O&M procedures. Caretakers need to be trained on RO plant technology by the project implementers.[5] Use of a standard operating procedure manual for each RO plant is also important to ensure effective O&M. Typically, caretakers are hired from the local community. They are paid around 5,000 to 7,000 Bangladesh taka (BDT) (US$59–82) per month, depending on sales from the RO plant.

Management of the RO plant and the handling of funds, payments to suppliers, and strategic decisions are the responsibility of the WMC—a diverse body made up of local people, including women who serve in leadership positions with financial decision-making authority, faith leaders, and teachers with links to local government officials. Customized training was provided by Nobo Jatra to both RO caretakers and WMC members and covered O&M, water safety plan management, business development and marketing outreach, and technical skills training for caretakers. WMCs provide training in technical trouble shooting and in business management, including record keeping and customer relations. Committee members are also able to supervise O&M in collaboration with plant caretakers, which helps to ensure that there are no interruptions to water supplies or prolonged delays caused by outstanding repairs. During the WMC formation process, Nobo Jatra staff sensitized the community to the importance of having a diverse committee with a cross section of members that includes teachers, faith leaders, influential local people, and those from vulnerable and extremely poor households. Once committees

FIGURE 2. The Moutala RO WMC in southwest Bangladesh led by a woman president (4th from left) and cashier (3rd from left) *(photo: Nobo Jatra)*

5 The caretakers have a secondary school certificate degree so that they are able to keep basic sales and income-expense records and conduct daily mechanical operation of the RO plant. The caretakers are trained in O&M of RO plants, water safety plans, and basic WASH concepts.

were formed, to avoid ceremonial token leadership roles, Nobo Jatra provided leadership training to women so that they are able to effectively lead within the committees with confidence. The leadership training included tips for public speaking, problem solving, and negotiation skills. WMCs are also instructed in capacity building of O&M water points, water safety plans, and basic WASH concepts.

For example, the Moutola RO WMC is led by a woman president, Sabina Yeasmin, and consists of fourteen members with 50 percent female representation, including a woman vice president and cashier (see fig. 2). The committee comprises faith leaders, teachers, farmers, homemakers, and local businessmen. There are three trained caretakers working on this RO plant, two of whom are women. The Moutala RO plant sells an average of 70,000 liters of water per month, covering approximately 250 households.

Table 1 shows the typical water production and costs of an existing RO plant in the Nobo Jatra project area.

TABLE 1. Water production and costs for a Nobo Jatra RO plant in southwest Bangladesh

Monthly income and expenditure for RO Plant with a peak capacity of 1,000 liters per hour						
Consumption (Liter)	Income (BDT)	Regular expenses (except uncertain maintenance costs)			Total Expense	Balance
		Electricity bill	Filter replacement	Caretaker's salary (average)		
70,000	28,000 (US$331)	8,000 (US$94)	2,000 (US$23)	6,000 (US$71)	16,000 (US$189)	12,000 (US$142)

Nobo Jatra put this knowledge and experience into practice by establishing ten pilot RO plants in 2019–20, each one carefully sited where electrical power was available, traditional water options such as deep tube wells were less viable, and demand for water was likely to be buoyant. The plants were also equipped with backup generators. The newly convened WMCs fine-tuned the business plan for each RO plant; no two business plans were exactly alike. Prices for water were set independently by the WMCs, and the salary of the plant caretaker was partly dependent on water sales. The price of the water was fixed in consultation with the local community, balancing the need for income generation with the imperative of serving vulnerable communities who most need safe drinking water.

Nobo Jatra also soon made use of the local institution of water vendors who deliver water directly to the doorsteps of customers using three-wheeled cargo-carrying bicycles known in Bangladesh as "vans." This service greatly reduces the time and effort it takes to collect and carry water, and it proved immediately popular in the delivery of RO water. Furthermore, once there were lockdowns for COVID-19, public transport became scarce and people were reluctant to leave their homes due to fear of illness. A COVID-19 impact assessment in 2020 carried out by Nobo Jatra found that nearly three-quarters of Nobo Jatra's participant households reported that it took longer to collect water due to longer queues, social distancing measures to reduce the number of people at water points, and limited local transportation options.

The water vendors played a critical role during this time, making sure that families were able to access safe drinking water during the pandemic and sustaining market outreach. At the time of writing, more than forty water vendors collect water from the RO plants and deliver it to customers, and thus far they have together sold around 4.5 million liters of water. Nobo Jatra also instituted a card-based payment system, making it simpler for community members to pay for water and reducing the need to handle cash at the RO plants[6] (fig. 3).

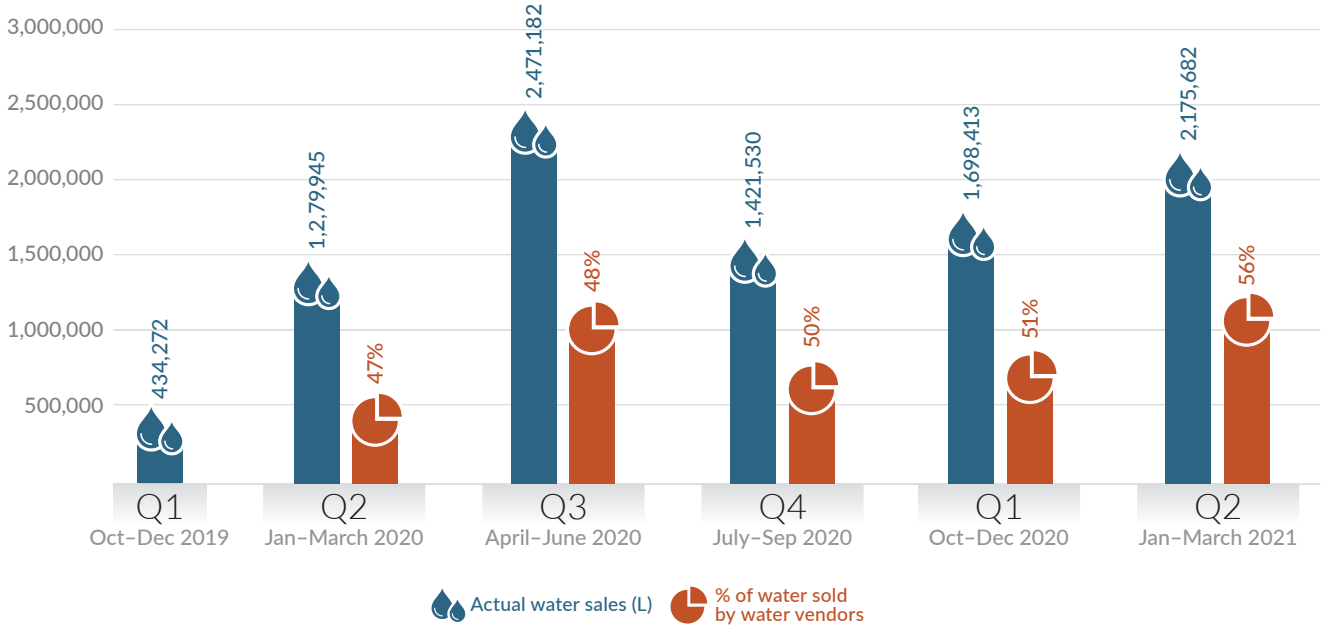
6 Nobo Jatra emphasizes poor and disadvantaged households in its work, which is reflected in the cost of RO water at US$0.004 (about 0.4 Bangladeshi Taka) per liter.

Water Management Committee members provide messaging on the importance of accessing safe drinking water from the RO all year round.

FIGURE 3. Cashless payment system at an RO plant *(photo: Nobo Jatra)*

To date, all ten RO plants are fully functional, and sales are steadily improving (fig. 4). In FY2019/20, the ten RO plants sold a total of more than 9.4 million liters of water, with a combined total income of around US$41,188. Income from water sales covers about 86 percent of the total O&M costs of the ten RO plants, while the remaining costs are covered through water tariff collections by the WMCs. Remarkably, all ten RO plants functioned consistently throughout the year and in the aftermath of Cyclone Amphan in 2020; while many water points in the area were damaged, the RO plants continued to supply communities with safe drinking water. In the worst affected locations, the government purchased water from the ROs and distributed it at the community level, and in some cases, WMCs voted to donate water in areas with widespread damage to infrastructure.

FIGURE 4. RO plant sales



CRITICAL FACTORS FOR SUCCESS

Reflecting on their experience with the ten pilot RO plants, Nobo Jatra project members identified certain factors that were critical to the success of the project:

1. **An incremental approach to complex projects is essential, as is gleaning insight from past experience.** In terms of technology, ROs are feasible in southwest Bangladesh. However, before starting the pilot RO plants, Nobo Jatra carried out a field-based learning exercise to understand the factors that enabled or hindered the sustainability of ROs established in the Nobo Jatra project areas (by the government or other NGOs) in the past. Nobo Jatra was able to identify past challenges, including inadequate O&M, governance gaps, reluctance to pay for water, and poor electricity connections. These factors informed the design of the Nobo Jatra pilot RO plants and their institutional underpinnings.

2. **Collaborating with local government and influential local elected persons and communities is critical.** These local elected persons are important allies who can promote the use of RO plants, and in some cases, they or other influential individuals within communities donated land on which the RO plant was constructed. Consistent messaging on the value of the RO plants, consistent access to safe drinking water, and social and behavior change helped to shift mindsets around paying for water.

3. **A diverse, inclusive WMC is important.** This goes beyond gender balance and includes teachers, faith leaders, influential individuals, local residents, and other representatives. Having women in leadership positions on the WMCs with decision-making authority, as president or cashier, for example, was found to be particularly effective in terms of governance. To date, 53 percent (female–4,215; male–3,686) of WMC members are women. Remarkably, 1,005 (12.7 percent) women hold leadership positions as presidents, vice presidents, treasurers, and general secretaries and lead decision-making on resource allocation for repair, monthly tariff collections, and monitoring of water points.

4. **A viable business model is vital.** Enabling water vendors to expand markets by delivering water to businesses and families in wider catchment areas proved to be key. At present, the RO machinery is relatively new, but future failures are anticipated as it ages, and the business model and income stream has allowed the establishment of a long-term fund to provide for repairs. Funds generated through RO plants are deposited in bank accounts (each RO plant has its own bank account managed by the respective WMC) and the WMC determines how the funds are used for repair and maintenance or other troubleshooting.

5. **Value was also found in sharing business and management progress updates**, including challenges and areas for required support, with local government bodies (such as Union Parishad, a grassroots tier of government that supervises health care, family planning, water, and sanitation services) and Government of Bangladesh units including DPHE personnel. When kept informed, these officials were then able to assist and support where necessary.

FIGURE 5. Well-managed RO plants can provide reliable drinking water *(photo: Nobo Jatra)*

CONCLUSIONS

A core aim of the Nobo Jatra project is to deliver sustainable supplies of safe drinking water to communities in the four project upazilas, particularly in those locations where existing traditional water sources were saline or otherwise unsuitable. A careful approach to installing, operating, and maintaining RO plants has so far proven successful, with ten pilot plants established in 2019–20. An incremental approach to understanding local conditions and factors for success, coupled with a carefully designed and executed business model, are critical. The role of RO plant caretaker, alongside the oversight and steering provided by the WMCs, forms an institutional backbone for plant operations and helps to ensure its financial and operational sustainability. The expansion of local water vendors has not only created employment opportunities but has also lessened the effort and time it takes for local people to obtain their domestic water.

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