Technical Briefing Note 26

DESALINATION

Dec 2020

SUMMARY

This document provides information on Oxfam's research on desalination technology, suppliers and lessons learnt from implementing desalination water treatment systems in several countries. It should be read in conjunction Oxfam's research report – A Road Map for Small Scale Desalination (2018) which provides a summary of current and emerging desalination technologies. Oxfam has installed small or medium scale desalination water treatment plants in Palestine, Syria, Iraq, Yemen, Somaliland, Bangladesh and Kenya with varying success. With the exception of a solar stills pilot project in Bangladesh, all are based on reverse osmosis (R.O.) technology, which account for the vast majority of desalination plants globally. Whilst desalination is becoming more affordable and new technologies emerging, for humanitarian response - due to cost and complexity, water treatment through desalination should be considered as a measure of last resort

BACKGROUND

Salinity is becoming an increasingly common problem within Oxfam programmes. Some groundwater is naturally brackish. However climate variability and increased frequency of drought is reducing groundwater recharge and leading to a deterioration in water quality in some regions. Elsewhere poor management and lack of regulation is resulting in over abstraction and intrusion of seawater (in coastal areas) or "upconing" of brackish water that may have been trapped in the rocks from when they were formed. Once an aquifer is contaminated in this way it can't be reversed.

Oxfam does not have a desalination kit within its Supply Centre because different source waters require different combinations of pre-treatment, treatment and post treatment which requires specialist advice. This document aims to provide practical guidance on factors that need to be considered if planning a desalination system.

DESALINATION OVERVIEW

The focus of the "Road Map" study was to provide recommendations for small scale desalination facilities. The report concludes that i) Solar still distillation (SSD) is the best choice for individual household use, due to its low capital investment and simplicity; ii) Reverse Osmosis (RO) is the most effective technology for small scale facilities (this was defined as 1-10m3/day but the recommendation is equally relevant for larger systems); and iii) Capacitive Deionisation (CDI) is an emerging technology which shows promise and is worth considering for raw water with salinity below 3,500ppm TDS as an alternative to R.O (further research has confirmed that performance of existing commercial CDI units significantly decreases above 1,000ppm limiting it application).

SALINITY MEASUREMENT AND CLASSIFICATION

Salinity refers to the concentration of soluble salts in water. All natural water contains some dissolved salts such as sodium, magnesium and calcium. Sodium chloride is the most common of all salts. There is no WHO health based guideline for salinity and the taste of water will generally be off-putting before it reaches a level where it is harmful for health. Salinity can be measured by electrical conductivity (EC) - expressed in µS/cm, or total dissolved solids (TDS) - expressed in mg/l or ppm. The conversion between the two is not constant and depends on the chemical content of the water, however 0.67 is commonly used as a conversion factor i.e. water with a T.D.S. of 2,000mg/l is approximately equivalent to an EC of 3,000 µS/cm. For the purpose of this technical brief salinity is expressed in TDS.

There is no universal agreement on what constitutes low, medium and high salinity water and acceptability will differ between consumers, Countries and depending on the application. The table below should therefore only be used as rough guide. For human consumption, 1,000mg/l TDS is commonly used as a limit to what could be classified as freshwater. Seawater has a typical TDS of 35,000mg/l.

Total Dissolved solids (TDS) mg/l and palatability for human and animal consumption

0 – 1,000	Suitable for all normal purposes
1,000 – 3,000	Suitable for livestock, marginal for human consumption
3,000 – 5,000	Suitable for livestock, unsuitable for human consumption
5,000 – 7,000	Suitable for camels, marginal for other livestock
7,000 – 10,000	Suitable for camels, marginal for goats and sheep, unsuitable for cattle
10,000 -15,000	Marginal for camels, only in emergencies for goats and sheep
>15,000	Unsuitable for any domesticated animal life

ALTERNATIVES TO RO TREATMENT

NON-TREATMENT OPTIONS

Given the challenges associated with successfully operating and maintaining a desalination plant, if treatment to remove salts or other chemical contaminants can be avoided then alternatives such be considered. Options are blending with a lower salinity water or developing new sources, if freshwater options exist. This may result in pumping and piping water from significant distance. In such circumstances a feasibility and cost analysis can be undertaken to determine which offers the best solution.

SOLAR STILLS

A solar still is a very simple technology based on evaporation and collection of condensed water droplets. It doesn't require electricity or any mechanical or moving parts and therefore has minimal associated operating expenses. It is equally effective for low and high salinity water. Solar stills may be appropriate for drinking needs of individual households in rural areas but because the output is so low, as number of users and demand increases, it rapidly becomes uneconomical and also impractical considering the large space requirements.

In 2013, Oxfam piloted two Fcubed Carrocell 3000 solar stills in Bangladesh. This is the largest of three models produced (with a 3m2 surface area) and the company claims that it can supply 20 litres of water per day (< 30 degrees Celsius). In Bangladesh they provided good quality water but only between 8 and 15 litres per day and on this basis the trial was terminated without scale-up. Oxfam Kenya considered introducing the same in its Turkana Programme but the $450 cost per household was a major barrier to replicability.

Several units can be set up as part of a larger module but the cost and space required increases in a near linear way.

Iraq (Innovation Lab) partnered with Aquaba with the aim of local production of solar stills. The company produces a solar still costing $150 (1m2 surface area) which it claims is able to produce up to 5 litres of water per day.

Solar stills can be improvised with local materials – glass or even plastic sheeting at much lower cost to commercial products but efficiency drops accordingly, so it may be a false economy.

Although the simplest technology, the price per litre of water from a solar still makes it the most expensive desalination technology. **Solar stills have their "niche" but are not appropriate for emergency WASH response where Oxfam needs to deliver water to communities at scale.**

CAPACITIVE DEIONISATION (CDI)

CDI uses low voltage DC current and electrodes to generate electrostatic forces which manipulate positive and negatively charges ions into separate brine and freshwater streams.

For low salinity water, CDI requires less energy compared to R.O. and has favourable recovery rates (80+%). CDI cells are also reportedly less fragile than R.O. membranes but pre-treatment is still required to remove particulate and organic matter which would otherwise clog the modules. Following the Road Map research, Oxfam has held discussions with several leading companies and or individuals specialising in CDI technology. At the time of writing existing commercially available CDI systems appear only to be able to cope with a raw water with a TDS limit of 2,000ppm or below which severely restricts where the technology can be used and therefore their usefulness in Oxfam programmes.

CDI appears to be working well in India which commercially produces CDI cells and has established rural water kiosks supplying CDI treated water. To fully assess the potential of CDI for Oxfam programmes we are seeking suitable sites for a trial but to date

Figure 2: A CDI cell. Innodi - India

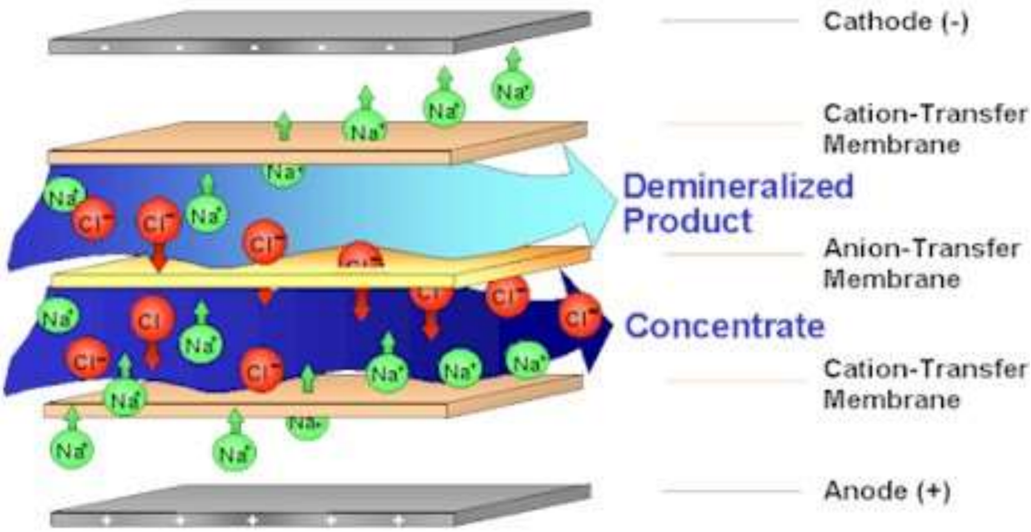

Figure 1 – CDI Process

the limited salinity range has prevented this. **CDI is still an emerging and evolving technology. It has potential but it may be several years before reaching a state where it can be useful to our programmes.**

REVERSE OSMOSIS (RO)

Reverse Osmosis is a process where water is de-mineralised and de-ionised by pushing it under pressure through a semi-permeable "reverse osmosis" membrane which allows some atoms and molecules to pass through (as permeate) whilst preventing others (rejection/brine) – For a community scale water treatment system, R.O. is currently the only realistic option for Oxfam programmes. The basic mechanical fundamentals associated with R.O. are fairly simple i.e. use an electric pump to generate a water pressure sufficient to force water molecules through a membrane (the trans-membrane pressure to achieve this ranges from 5 bar for low salinity water to upto 84 bar for seawater). However, the multiple pre-treatment stages to remove impurities from the water which are not compatible with R.O. membranes, the care required to look after the membranes, and post treatment remineralisation and chlorination to avoid recontamination, collectively make an RO system quite complex. To make an informed decision on whether R.O. is appropriate, it is important to have at least a basic understanding of the principles of operation.

TERMINOLOGIES ASSOCIATED WITH RO

RO membrane – modern membranes are commonly thin film composite consisting of 3 layers: a polyester support web, a microporous interlayer and an ultrathin polymide barrier. This is packed in a spiral-would configuration of "leaves" with a leaf made from two membrane sheets glued together with a permeate spacer between them (figure 3).

A part of the feedwater – typically 10-20%, passes through the membrane and exits as permeate. There are many different types of membrane to suit different purposes, feedwaters and required permeate. "Dow" which manufactures "Filmtech" RO membranes has the follows three broad classes:

Membrane Class	Range (TDS)
Tapwater (TW)	Upto 2,000mg/l
Brackish (BW)	Upto 12,000mg/l
Seawater (SW)	8,000-50,000mg/l

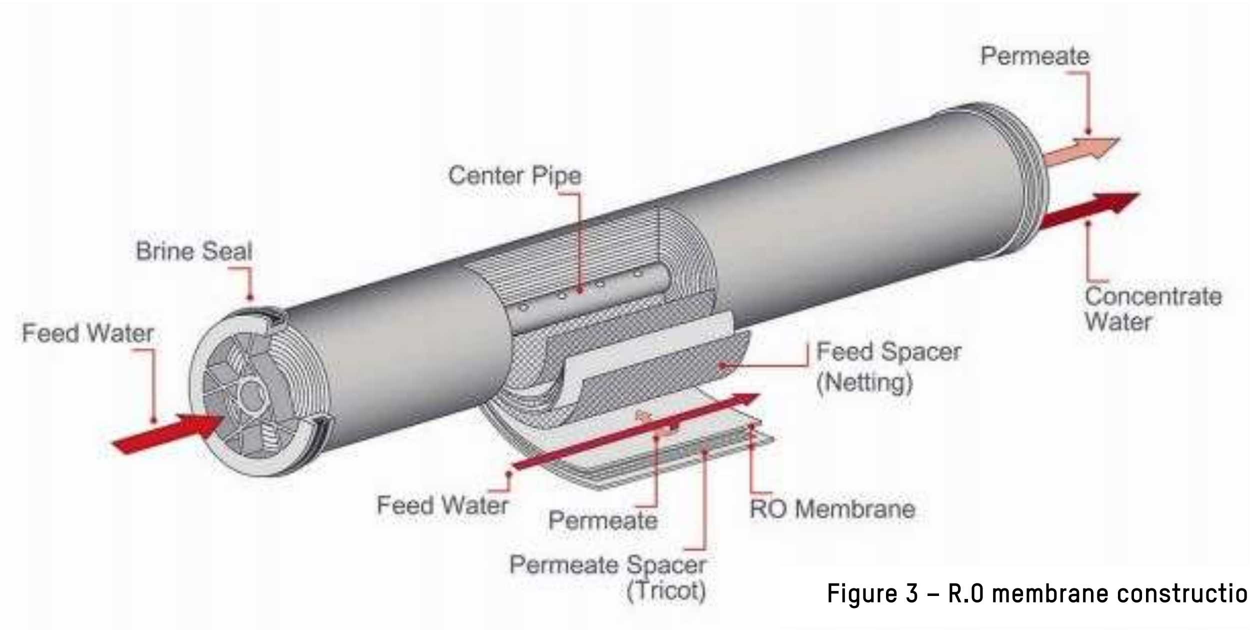

Figure 3 – R.0 membrane construction

The class and type of membrane will depend on the chemical composition of the feedwater and should be determined by RO specialists. R.O. membranes come in standard sizes so different brands should be interchangeable. Standard nomenclature is sequenced as follows - Class (TW,BW,SW), Element Family – diameter (inches x10), Length (inches)

Figure 4 – R.O membrane

E.g. the above membrane installed by Oxfam in Kenya is for Brackish water (BW), high rejection element family (30), 4 inch diameter (40), 40 inch length (40).

Membranes are the most expensive and sensitive component of an RO treatment system and without proper care can be spoilt very easily.

Pressure vessel – several RO membranes, usually from 1 to 6, may be contained in a single pressure vessel. Multiple pressure vessels may be set up in parallel to increase the volume of permeate reduced. Additional "stages" (or "passes") may be set up in series to increase the recovery.

Recovery/passage (%) – the volume of water passing through the RO membrane as "permeate" (treated fresh water). Recovery of upto 90% is possible with brackish RO systems. However, the cost and complexity of system increases accordingly as higher operating pressure is needed, risk of membrane scaling increases and additional O&M requirements are needed. Small to medium, sized RO systems used by Oxfam are likely to have a maximum recovery of 70%.

Rejection/concentrate (%) – the solute or total dissolved solids that cannot pass through the membrane and form a brine stream. Depending on the concentration of salts it may be possible to use this for non consumptive purposes such as washing and cleaning. If not, consideration needs to be given to safe disposal. The sum of the recovery and rejection equals the feed flow.

Stages – In a one stage system, feedwater passes through a pressure vessel once to produce separate permeate and reject streams. For brackish water, multiple stages are possible to increase recovery, with a maximum recovery of 50% from each stage. In a 2 stage system the reject from stage 1 becomes the feedwater for the second stage pressure vessels and the recovery from stage 2 is added to the permeate from stage 1. Assuming a 50% recovery at each stage, the overall recovery is 75%, and rejection 25%.

Array – this describes the physical arrangement of the pressure vessels in a 2 stage system. Because the volume of water going into the second, or even third stage is less than the previous one. For large systems multiple pressure vessels will be arranged in parallel in "stacks" with the subsequent stack in series and tapering down. A 2:1 array could have 4 vessels feeding into 2 vessels.

Concentrate recycle – as a more cost-effective option to having a second stage a proportion of the rejected brine can be recirculated and added to the feedwater to increase the system recovery.

Scaling – this can occur as certain dissolved (inorganic) compounds become more concentrated. The most common scaling is due to calcium carbonate ($CaCO_3$). Scaling occurs when solubility limits are exceeded, compounds come out of solution and precipitate on the membrane. Scaling significantly reduces performance by clogging of the membranes, leading to lower permeate flow and lower permeate water quality. A well designed system will reduce susceptibility to scaling which may require addition of an anti-scalant (pre-treatment) to the feedwater.

Fouling – is caused by accumulation of particulate, organic or micro-organisms clogging the membrane. Effective pre-treatment to remove harmful organics and micro organisms, and good design to ensure the velocity of water flowing across the membrane is sufficient to "sweep away" salts and prevent build up and clogging of the membrane surface.

Chemical attack – Modern thin film membranes are not tolerant of chlorine and other oxidisers, which if not removed will burn holes in the membrane pores and cause irreparable damage

Clean in Place (CIP) – involves periodically adding chemical solution to the pressure vessel, such as citric acid, to cleaning membranes without removing them and protect against fouling and scaling. A CIP system can also be used add chemical preservative to protect membranes. This is necessary if a system is not going to be used for several days to protect from spoiling.

PRE TREATMENT – the type and chemical composition of the feedwater will determine what pre-treatment is required. Common measures include:

Multimedia filtration (MMF) helps prevent fouling by removing particles down to 15-20 microns. A 5-micron cartridge filter would typically be placed after the MMF to prevent any breakthrough of filter media.

Microfiltration (MF) effectively removes colloidal and bacteria matter. Hollow fibre is most commonly used which requires periodic backwashing.

Anti-scalants/scale inhibitors – By adding to the feedwater an anti-scalant increases the solubility limit of the water and prevent precipitation of salts leading to scale formation. The choice of anti-scalant and correct dosage depends on the feedwater chemistry and RO system design.

Ultra Violet (UV) treatment kills bacteria preventing growth and fouling of membranes.

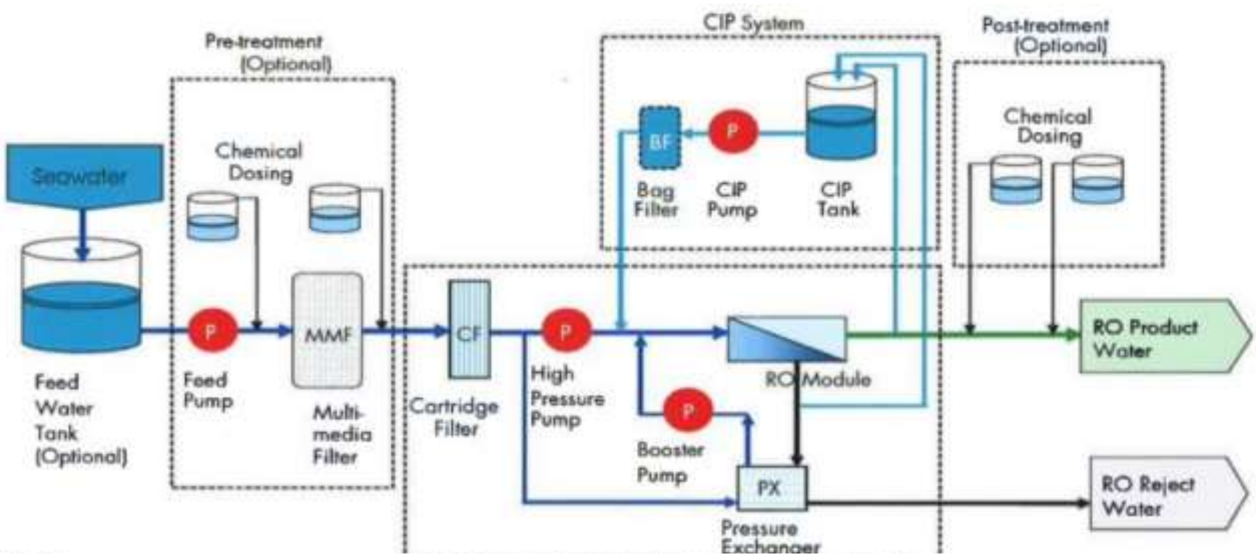

Figure 5 – Example process diagram for a Reverse Osmosis treatment system

POST TREATMENT

A well functioning R.O.system will typically remove 95-99% of "contaminants". This purified water tastes flat because it is not only stripped of harmful or excessive salts but also essential minerals. Post treatment rebalancing is required to re-mineralize and restore essential minerals to the water. Water should also be chlorinated.

KEY FACTORS WHEN CONSIDERING RO

There are three overarching considerations to determine whether reverse osmosis desalination is appropriate.

1. **Cost and affordability.** Desalination systems are perceived as being expensive but costs have reduced significantly in recent years. Solar PV provides a viable cheaper, greener energy source to fossil fuels reducing operational costs. Membrane costs have reduced in price in recent years and as new suppliers in the market, high quality affordable solutions are now available targeting the humanitarian-development market. Water supplied through an RO system does significantly increase its cost but where water is scarce, it may be a much cheaper long term solution to recurrent water trucking which is happening in Somalia, Ethiopia, Yemen and elsewhere.
2. **Technical complexity.** RO systems are arguably the most advanced water treatment technology available for water supply. When broken down into its component parts, a trained operator should be able to manage the pre-treatment, high pressure membrane and post treatment phases. However, not following required sequential procedures or simple errors like not opening the correct valve or carrying out routine flushing can have major implications. These are in addition to the usual O&M issues associated with any water supply system. It is therefore strongly recommended that RO systems are not appropriate for community management. A sustainable RO system needs access to specialist technical back-up support, e.g. service level maintenance and repair agreement, and a continuous level of technical oversite, requirements more associated with Utilities or privately-operated water provision.
3. **Water efficiency** – A well designed and maintained RO system should have a recovery of between 60 and 70%. Scaling/fouling problems can reduce the performance further. At the planning stage consideration needs to be given to finding a productive use for the 30-40% (perhaps more) reject water. In arid and semi-arid areas, a significant wastewater stream from pumping groundwater may not be acceptable to authorities and detrimental to the environment. Reject water may still be perfectly acceptable for non-consumptive domestic purposes such as washing and cleaning. There are also salt tolerate crops which could be irrigated with wastewater. Somaliland is considering whether the RO systems could create fish farms and new livelihood opportunities.

SOLAR POWERED RO

Photovoltaics provide a solution to the high energy costs associated with desalination. Specific design adjustments are required to optimise an RO system to be powered by PV so it is not the case that any RO equipment can just be wired to a PV generator of comparable capacity its diesel equivalent. Unlike solar pumping for water supply which have variable output (but which is buffered by ensuring adequate storage), RO plants are most efficient when operated on a continuous basis (and at continuous pressure and flow) which mains grid electricity or diesel generator provides.

Measures may include use of positive displacement pumps which tend to maintain pressure over a wider range of power input than a centrifugal pump. Variable speed motors, typical in all solar pumps provides soft start/stop and reduce the risk of mechanical stresses being placed on membranes. Pressure vessels can provide a buffer to compensate for period of short term cloud cover but this increases overall cost, and clever electronics within the control unit. Batteries are another option but as with normal solar water pumping, batteries are not recommended due to their expense, drop in performance over time and limited lifespan.

Figure 7 – Oxfam Somalia Solar RO system

Existing commercial suppliers - There are an increasing number of suppliers who specialise in solar RO solutions and claim to have patents which optimise their products for PV and differentiate them from other suppliers – Boreal Light, Mascara, Solar Water Solutions, Swiss Fresh Water, and Trunz are several known international suppliers.

Currently Oxfam does not have field experience and data from different systems so it is difficult to compare performance or distinguish what is a genuine technical difference compared to clever marketing. This makes it difficult to determine the performance or added value of importing a European designed and assembled RO treatment system compared to one which uses similar branded components but which has been designed and assembled at cheaper cost in Country. What is fairly certain however is that an RO treatment system designed and optimised to be powered by solar will be more efficient that a generic RO system designed to run off a stable continuous power source. It is important therefore to ask suppliers how the systems are adapted for solar power and whether the stated performance data – daily output and efficiency makes any allowances for the solar day and seasonality. In relation to output, it is normal to express output capacity based on the assumption of 24 hour continuous operation, so important to clarify. Other considerations apart from cost, production and efficiency are the quality of components used (Dow, Pentair, GE for example are reputable membrane and pressure vessel brands).

All PV systems should be hybrid and able to operate using a secondary back-up power source to extend operating hours or as an alternative to solar during periods of heavy cloud cover.

Indicative costs - For a complete containerised "plug and play" RO system with PV able to produce 1.7m3/hr (10m3/solar day) procured by Somaliland (2020) cost €50,000 (excluding shipping). Indicative costs for a larger unit with output of 10m3/hr (50m3/solar day) is €130,000. These are based on brackish water of below 6,000ppm T.D.S. Costs of Seawater units for TDS of 33,000+ppm – which are built to a higher specification to handle the greater operating pressures are considerably more.

OXFAM FIELD EXPERIENCE WITH RO

Obtaining information on the whereabouts and performance of existing Oxfam desalination has been challenging. Some have been handed over to other partners, some are no longer functioning and for others close monitoring and follow up has not been carried out. This is therefore not a comprehensive list and as new examples and lessons learnt emerge this can be updated.

OPTI – Gaza is reliant on groundwater, however 97% of the aquifer is contaminated by a combination of coastal saline intrusion (resulting from over abstraction) and high nitrate (due to infiltration of sewage and over application and leaching of fertilisers into groundwater). In this context, RO is the only way to supply potable water and there are over a hundred public desalination plants and a similar amount of privately operated systems to meet the needs of the 2 million inhabitants of Gaza. There is strong market and available technical expertise in Country capable of designing, assembling and servicing equipment. As a routine part of its humanitarian WASH work Oxfam in Gaza has rehabilitated, upgraded and developed new RO systems. In 2018 Gaza team installed its first PV powered RO unit (4.3m3/hr output) to mitigate widespread power rationing.

Figure 8 – Al Amal Solar RO system, Gaza

Somaliland – two solar powered RO systems were installed in rural villages in 2018. Both were still working in 2020 but have experienced considerable operational challenges. Some issues were identified at the planning stage and relate to management and implementation challenges rather than the technology itself. These include i) selecting remote rural locations where ongoing technical support was difficult to provide; ii) insufficient community engagement including failure to understand demand and willingness to pay; iii) under estimating and ignoring advice related to the management capacity/structure required to successfully manage a system; iv) unclear roles and responsibilities between Oxfam, Government and Community or mechanism for resolving problems. Technical problems have also been experienced. The membranes became spoilt and required replacement within weeks of installation and both systems are performing below the 7,500 litres per solar day expectation, producing lower permeate and higher rejection.

In 2020, two additional units of higher capacity (10m3/day, based on 6 hrs of solar operation, 65% recovery) were installed in other villages. It is hoped that the lessons learnt from the initial two units will benefit these installations. The technical design of the treatment units has changed with increased automation to simplify operation and reduced the risk of human error. As part of this electronic flow valves are incorporated. The supplier (Boreal Light) will also take responsibility for operating the unit for 12 months before handing it over to ensure any performance issues are addressed.

Yemen –procured a solar RO unit of 12m3/day capacity from the same supplier of the treatment units for Somaliland (Boreal Light). It has experienced significant teething problems but mainly unrelated to the technology itself (high staff turn-over, lack of close oversight which resulted in the treatment unit being oversized for the water source which reportedly dries after 1-2 hours of pumping). As a substitute for timely technical support from Oxfam, the village operator was able to communicate directly with the supplier in Germany via Whatsapp. At the time of writing Oxfam had addressed earlier issues and the system was performing well, producing 10m3/day at 60% water recovery and generating an income for the village.

At least one other RO system is installed in North Yemen. Technical information is lacking, other than the system was not operational in 2019 during a GHT advisor visit.

GUIDANCE & LESSONS LEARNT

Desalination based on RO is a complex treatment process that requires skilled expertise which is well beyond the means of a typical water committee and community level technicians. An RO system requires professional management which is often lacking in contexts where Oxfam works. Examples of success are most prevalent where they are run as a business and where technical capacity is readily available, e.g. Gaza.

Ensure adequate **consultation** during the planning stage. Consider willingness and ability to pay during project planning. In Yemen people were prepared to pay for water but they were accustomed to it being delivered to their house. The desalination plant Oxfam supported provided water at cheaper cost and better, guaranteed quality to that which was provided by vendors, but the service level was not the same as it was several hundred metres away. Consequently many households continued to use water trucking vendors. In Somaliland a willingness to pay survey was done which appeared to confirm the economic viability of the system however it didn't take account that people prefer "berkad" water (underground rainwater harvesting reservoirs). Consequently, during the rainy season, many people stopped buying desalinated water affecting the economic viability of the RO plant, which needs to remain operational year round to avoid membranes becoming spoilt.

Ensure sufficient project oversight and capacity building. The desalination systems Oxfam installed in Somaliland were the first of their kind in Country and the performance and hopefully success of the project aimed to inform the rest of the WASH sector. Close oversight, essential to ensure technical support and for learning was impossible because sites were several hours away from the nearest Oxfam field office. The community chose operators with low literacy level and little or no understanding of English which made training more difficult It was eventually agreed to hire younger school educated literate operators with basic understanding of English.

Plan for wastewater use/disposal from the beginning. For well managed/operated RO systems at least one third of water produced will be brine waste stream or reject water. In a semi arid context it is unlikely to be acceptable to discharge this water to waste. Countries may also have environmental restrictions on where and how highly saline water can be discharged. Subject to community consultation and agreement "reject water" may still be suitable for non-consumptive purposes (washing and cleaning) and possibly even for cooking so it can still be productively used if provided at reduced tariff or free. There are also creative opportunities to utilise brine water for salt tolerant crops or even fish farming. Discharge of brine to waste should be a last resort as it is inefficient and potentially environmentally damaging.

Ensure well trained, literate operators are chosen to take care of the system. This is particularly helpful in communicating problems and when remote troubleshooting is required. Daily

Figure 9 – Oxfam Somalia RO system components (Boreal Light)

logbooks which record pre and post filter pressure, feed, permeate and concentrate flow and TDS, enable changes in performance over time to be checked. As a rule of thumb a 15% drop in performance means that cleaning and overhaul is necessary. For the RO unit in Yemen, because the operator understood English, he was able to communicate via WhatsApp directly with the manufacturer in Berlin and send photos illustrating the problem. This enabled the remote diagnose of a problem within the control panel and one of the pressure filters (which had been damaged when the wrong valve was closed). The opposite was true in Somaliland due to the poor literacy of the operators.

Professionalisation. Consider operating the desalination unit as a business. This goes beyond training operators and considering a spare parts and consumables supply chain. It requires a business plan that considers willingness and ability to pay, the service level expected by customers, measures to ensure the needs of the most vulnerable are not excluded. A locally based entrepreneur or commercial business entity is more likely to be able to meet these requirements than a traditional village water committee.

CONCLUSION

Reverse osmosis is currently the only viable technology for humanitarian programmes to remove salinity at Community level scale. Oxfam has implemented desalination projects in several Countries, but with the exception of OPTI, which possesses considerable expertise in country, it remains unclear whether any of these projects will prove to be sustainable in the medium to long term. The level of complexity for desalination plants is beyond the capacity normally associated with community managed projects and is more typical of a professional water utility – with onsite technical expertise, private sector back up/service agreements, and management capacity to effectively manage revenue to meet the considerable recurrent and replacement costs. A thorough analysis should be undertaken prior to investing in a desalination project as there are many pitfalls. Oxfam can't control everything or guarantee long term durability, but design needs to factor in these challenges – particularly internal and external technical expertise, clear demand, willingness and ability to pay, a business model not dependent on community management. All of this requires time, resources and perseverance, which realistically requires a multi year programme commitment to have any chance of success.

PROJECT PLANNING CHECKLIST

Economic

What is the cost of supplying water through desalination (considering salaries, consumables, service and maintenance, replacement parts)?

Are there any alternatives to desalination? If so has a cost benefit analysis been done?

Will people be willing and able to pay for the water?

Has a willingness to pay survey been done?

Will people pay for water even during rainy season when there are alternatives? If not, is it economically viable

What measures are in place to ensure water is accessible to marginal/vulnerable households how cannot afford to pay?

Technical

Is specialist expertise available at regional or National level for regular servicing, troubleshooting and provision of replacement parts?

Has post installation monitoring, follow up and technical support been built into the project and budgeted?

Are project sites accessible to ensure sufficient technical oversight is on hand during planning, implementation and post completion phases?

Who will be responsible for management of the desalination plant long term? What evidence is there that this entity has the capacity to sustain complex equipment?

If there is no proven track record or there is uncertainty, what are the mitigation measures and is there a Plan B?

Is the water source reliable year round and are there any significant season fluctuations in salinity or turbidity that needed to be taken into account?

What is the expected efficiency of the system and what will happen to the waste water stream?

Are educated technicians available who can be trained to undertake basis operation and maintenance (literate, able to communicate effectively with remote support to troubleshoot (which may require knowledge of multiple languages).

Is there an existing supply of antiscalant, other consumables and replacement parts in the local market - pre filters, replacement membranes etc?

What measures are in place should the desalination plant fail to meet its design and performance targets? Retention fee? Build, operate and transfer model?

REFERENCES

A Road Map for Small Scale Desalination

What is Reverse Osmosis?

Dow Filmtech RO Technical Manual

What is capacitive deionisation?

Membrane capacitive deionisation webinar? (particularly mins 14.00-30.00)