WATER EXPERTISE AND TRAINING (WET CENTRE)

Action Research on Solar-powered Reverse Osmosis Treatment Plant Installed by DACAAR in Qala-e-Gulbaz Village in Kabul

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1. Background

Established in 1984, DACAAR is non-governmental, non-profit development and humanitarian organization that supports vulnerable people in rural areas of Afghanistan. It operates in the following thematic areas: Water, Sanitation, and Hygiene (WASH), Natural Resource Management (NRM), Women Empowerment (WE), and Small Scale Enterprise Development (SSED). In addition, DACAAR is a partner to the Citizen Charter Afghanistan Project (CCAP). DACAAR's interventions primarily target returnees, internally displaced persons (IDP), and their host communities and have benefitted over eleven million Afghans across almost all 34 provinces in Afghanistan. DACAAR's main office is located in Kabul and it also has six regional offices: East (Jalalabad), Central (Kabul), North-east and North (Mazar), South (Kandahar), North-west (Maimana) and West (Herat).

In partnership with Centre for Affordable Water and Sanitation Technology (CAWST), one of DACAAR's key programs is a Water Expertise and Training Centre (WET Centre). It provides water and sanitation trainings to WASH stakeholders, technical consulting to new or existing WASH programs and conducts action research. The WET Centre has a laboratory for water quality testing and has all the required equipment to test physical, bacteriological and chemical qualities of water. The laboratory provides water quality testing services to DACAAR WASH projects and external clients.

The salinity and chemical contamination of groundwater in Afghanistan is a common phenomenon, particularly in the provinces in the north, northeast and northwest. Despite the progress of various WASH technologies, very little has been done to deal with this particular problem. Following an experiment by World Vision in Badghis province, DACAAR started in 2018 a pilot project of Solar-powered Reverse Osmosis treatment system in Kabul province. The pilot included the construction of a deep production well and two elevated reservoirs in an area affected by groundwater salinity and chemical contaminants. DACAAR installed a reverse osmosis ultra-filtration system that was imported and set-up with the help of *Silicon Solar Company*. Furthermore, a community-based operation and maintenance system was established, based on the collection of user fees. During 2019 the WET Centre conducted action research about the project and whether this technology can be applied in small communities.

2. Rationale of the Research

DACAAR implemented different types of rural water supply systems, such as tube wells fitted with hand pumps, spring-fed gravity-flow piped water supply systems, motorized and solar-powered piped water supply systems, and bio-sand filters for household water treatment. DACAAR plans to introduce sustainable technologies, such as Reverse Osmosis desalination for saline water treatment in areas affected by groundwater salinity and chemical contaminants. Then, DACAAR plans to scale-up the RO filtration technology if the pilot turns out to be feasible and sustainable in providing safe drinking water to small communities.

3. Objectives of the Study:

Different types of bio-sand and ceramic filters for households have been studied extensively but the *solar-powered RO filtration* is a concept that has only recently been developed and requires further study. The main purpose of this action research is to evaluate the performance and effectiveness of the system in removing salinity and contaminants from the water and whether the system provides the quantity of water according to the specifications. DACAAR also wanted to study the O&M of the system and gain experience in installing the filtration system.

The specific objectives are:

1. Identify whether the RO filtration system's *efficiency* in removal of physical, bacteriological (E-coli bacteria) and chemical contaminations (salinity and boron) is according to the required specifications.
2. Check whether the quality of the treated water is within the WHO recommendations and Afghanistan National Drinking Water Quality Standard.
3. Measure the water treatment capacity of the RO filtration system (liter/hour), the amount of water refused/wasted and compare it with specifications of the RO filtration system.
4. Document the methods and costs involved in building, installing and operating the RO plant.
5. Disseminate the findings of the research about the efficiency, cost, and O&M of the RO plant.

4. RO Plant and Water Supply System Description

A solar-powered RO filtration system (from ROsolution.pk) with the capacity of filtering 10,000 GPD (gallons per day) of raw water with solar array size of 9.5 KW and two inverters (one for pressure pump and another for rest pumps of 5.5 KW) were installed in 2018 by *Silicon Solar Company* with the support of DANIDA (ROI) funds. Annex-1 shows the RO Plant Block Diagram and all parts of the plant and their connections. Annex-2 includes the RO Plant Accessories and Operation.

DACAAR constructed the water supply system: a tube well with 2.9 l/s safe yield (see Annex-3 for the tube well detail), a 6m elevated RCC reservoir of $10m^3$ capacity for source water/raw water storage, a 12m elevated RCC reservoir of $20m^3$ capacity for filtered water storage and the distribution piped network with 152 metered house connections. The water is pumped from the tube well to the 10 m^3 reservoir, then to the RO filtration plant and then the filtered water is pumped to the 20 m^3 reservoir that supplies water to the household connections. Solar energy is used for all the pumps in the system. Chemicals are used in the operation of the system, such as antiscallant for cleaning of the RO membrane filter, minerals for re-mineralization of the filtered water and sodium hydroxide for boron removal. Around 2,135 individuals (305 families living in 152 households) are benefiting from the system. The costs of the system are illustrated in Annex-4.

A Water Management Committee (WMC), consisting of one leader and 8 members, was established. The contractor trained one person from the community for operation and maintenance and provided the required tool kit and consumables. The WMC collects fees from the users on a monthly basis according to the water meter readings. The details of the costs are listed in Annex-5.

5. Methodology

The action research was conducted by DACAAR WET Centre and supported by DACAAR's Technical Unit and the Central Regional Office.

Step-1: Water quality analysis (WQA)

- Samples from source water and filtered water was collected on a weekly basis.
- Water quality testing was started in April and ended in November 2019.
- A lab technician was assigned and regularly collected and analyzed the water samples.
- All water quality testing results and findings were recorded (Annex-6).

Step-2: Resolving water quality issues

- WQA results were shared with DACAAR's Operation and Technical Unit and the contractor.
- Water quality parameters which were outside the norm were highlighted, discussed and remedial action was taken.
- Water quality testing continued and results were shared until all water quality issues in the filtered water were resolved.

Step -3: Data collection

- A questionnaire was prepared and information collected on the system components (Annex-7).
- Information about the system components and the beneficiaries was collected.

Step-4: Data collection on operation and maintenance (O&M)

- A questionnaire was prepared. (Annex 8).
- Data was collected on the O&M of the system from WMC and DACAAR staff.

Step-5: Data collection on safe water storage, quality, quantity and use of the filtered water

- A questionnaire was prepared to collect information from the users on water storage, quality, quantity and use of water (Annex-9).
- A 10% sample of the user families was randomly selected.
- Data was collected by interviewing the selected families by a health promotion couple from DACAAR Central Regional Office using the questionnaire in Annex-9.

Sep-5: Data analysis and reporting

- The data was analyzed after completion of the research in December 2019 and this is the final report of the action research which includes research methodology, water quality testing details, research outcomes and recommendations.

6. Results

6.1 Water Quality Tests' Results

Water quality testing started soon after the operation of the RO plant in April 2019. In total 8 water samples from the source water (tube well) and 23 samples from the filtered water (of the RO plant) were regularly collected and tested.

6.1.1 Salinity and Total Dissolved Solid (TDS) Removal Efficiency

The salinity (EC) and Total Dissolved Solid (TDS) of source water were significantly above the limits, WHO recommendation and ANDWQS. The EC and TDS removal efficiency of the RO plant was very high and the filtered water is therefore re-mineralized; mineral water classified as water containing at least 250 parts per million (mg/l) total dissolved solids (TDS). See tables below for details:

Table #1: Salinity (EC) comparison of source and filtered water (RO Plant)

Statistics	EC in Source Water (μS/cm)	EC in RO Filtered Water (μS/cm)	EC Removal	WHO Recommendation	ANDWQS
Maximum	6480	310	95.23%	≤1500 μS/cm	≤3000 μS/cm
Minimum	5250	79	98.50%		
Average	5490	166	97.0%		

Table #2: TDS comparison of source and filtered water (RO Plant)

Statistics	TDS in Source Water (mg/l)	TDS in RO Filtered Water (mg/l)	TDS Removal	WHO Recommendation	ANDWQS
Maximum	4458	213	95.22%	≤ 1000 mg/l	≤ 2000 mg/l
Minimum	3612	54	98.50%		
Average	3776	111	97.0%		

6.1.2 Turbidity Removal Efficiency

The turbidity of source water was within the limit, and the turbidity of the filtered water was less than the source water. Normally, the turbidity of drinking water should be lower than 5 NTU according to the WHO Recommendation and ANDWQS. Refer to Table # 3 for details.

Table # 3: Turbidity comparison of source and filter water (RO plant)

Statistics	Source Water Turbidity (NTU)	Filtered Water Turbidity (NTU)	Turbidity Removal	WHO Recommendation and ANDWQS (NTU)
Average	1.16	0.40	65.52%	≤ 5

6.1.3 PH (potential hydrogen) Change

PH of the source water and the filtered water were within the limit, but the filtered water had less pH than the source water. Refer to Table #4 for details.

Table # 4: pH comparison of source and filter water (RO plant)

Statistics	Source Water pH	Filtered Water pH	pH Change	WHO Recommendation	ANDWQS
Average	7.96	7.75	2.64%	6.5 - 8	6.5 - 8.5

6.1.4 Chemical Determination

All the chemical determinations of the filtered water from the RO plant were within the limit except boron. Boron tested 23 times from April to November 2019 and the average value is found to be 2.8 mg/l which is higher than the limit (2.4 mg/l).
Refer to Table #5 for details.

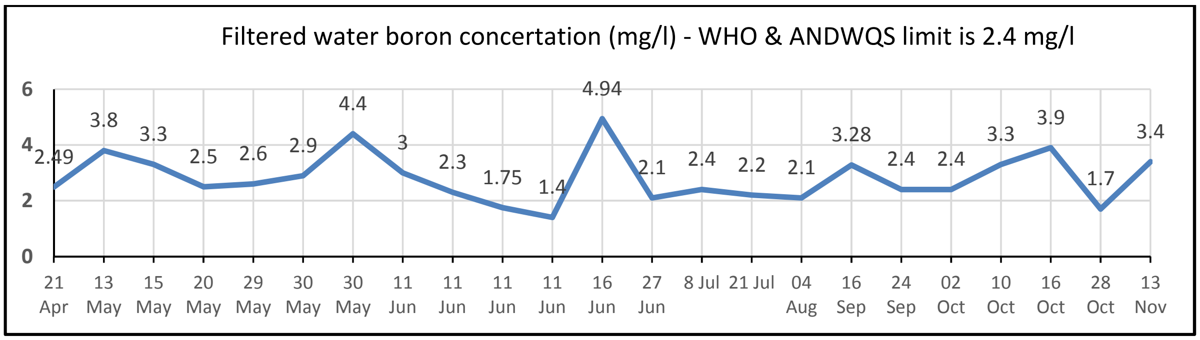


Table # 5: Chemical quality comparison of source and filter water (RO plant)

Anion	**Source Water (mg/l)**	**Filtered water Average (mg/l)**	**% Removal**	**WHO Recommendation**	**ANDWQS**	**Comments**
Total Alkalinity	310	26.3	92%	-	-	
Alkalinity P	10	9.6	4%	-	-	
Alkalinity M	360	42.5	88%	-	-	
Bicarbonate	340	24.5	93%	-	-	
Carbonate	20	16.7	17%	-	-	
Hydroxide	0	0	0	-	-	
Chloride	1125	55	95%	*250*	250	*Taste*
Sulphate	1317	17.5	99%	*250*	250	*Taste*
Sulphite	2	6.5	-225%	-	-	
Sulphide	0.02	0.003	85%	-	-	
Fluoride	5.2	0.3	94%	1.5	1.5	*Fluorosis*
Nitrate	284	7.3	97%	50	50	*Blue baby syndrome*
Nitrite	0.322	0.05	84%	0.2 – 3	3	*long - short term exposure*
Phosphate	0.15	0.03	80%	-	-	
Boron	6.3	2.8	56%	2.4	2.4	*Testicular lesions*

Bromide	0.38	0.31	18%	-	-	

Cations	Source Water (mg/l)	Filtered water Average (mg/l)	% Removal	WHO Recommendation	ANDWQS	Comments
Total Hardness	850	41.3	95%	*300*	500	*Taste and incrustation*
Calcium Hardness	140	12.6	91%	-	-	
Sodium	1267	47.8	96%	*200*	200	*Taste*
Potassium	10	1.3	87%	-	-	
Calcium	56	5	91%	-	-	
Chromium	0.02	0.015	25%	0.05	0.05	Cancerogenic
Magnesium	155	14	91%	-	-	
Ammonium	0.28	0	100%	*1.5 – 35*		*Odour - taste threshold*
Manganese	0.017	0	100%	0.4		*> 0.1 affects taste and stains laundry*
Copper	0.22	0.16	27%	*2*	2	*Taste*
Aluminum	0.01	0.01	0%	-	0.2	
Total iron	0.14	0.03	79%	*0.3*	0.3	*Taste and odour*
Total Arsenic	0.015	0	100%	0.01	0.05	

Other components	Source Water (mg/l)	Filtered water Average (mg/l)	WHO Recomm.	ANDWQS	Comments
Silica	28	3.12	-	-	
Hydrogen Sulphide	0.0212	12.6	*0.100*	-	*Taste and odour*
Residual Chlorine	0	0.003	0.2-0.5	0.2-0.5	

6.1.5 Bacteria Removal Efficiency

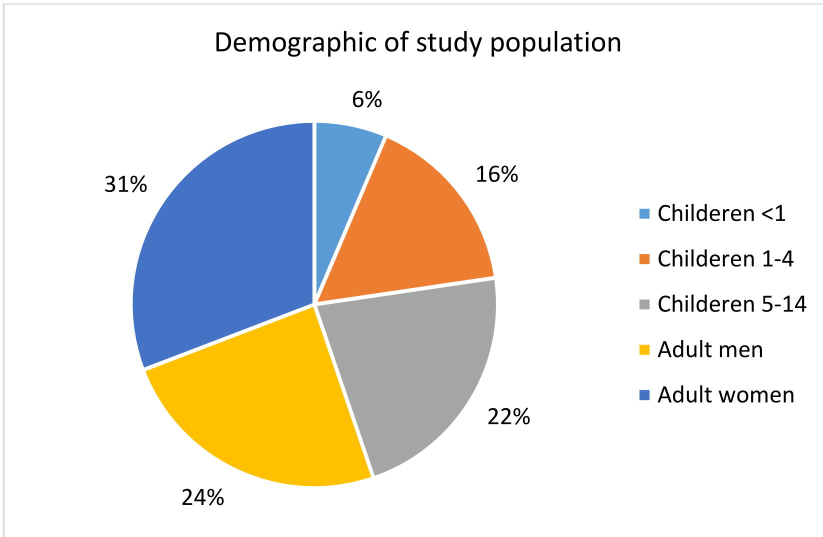
Bacterial Removal Efficiency was 100%. The bacterial removal from source water was very good and in all the tests there was no bacteria found in the filtered water, while the source water had bacteria. Refer to table # 6 for details.

Table # 6: Bacterial quality comparison of source and filtered water (RO Plant)

Statistics	Bacteria in RO Filtered Water (cfu/100ml)	Bacteria in Source Water (cfu/100ml)
Maximum	0	55
Minimum	0	0
Average	0	10

6.2 Demographics

Sixteen (16) households were surveyed with 172 people, an average of 11 people per household. The range was from a 4 to 22 people per household. In Afghanistan, a person is considered a child until he or she reaches 15 years of age. Using this definition, 45% were children and 6% were infants, under 1-year-old were; children aged 1 to 4 accounted for 16%. The 5 to 14-year-old children accounted for 22%. The adult women outnumbered the men with a ratio of 24 to 31.



6.3 Observation of Water Storages at Household

6.3.1 Findings

The households were storing the drinking water in containers (mostly in jerry cans). Since recontamination of treated water is a common problem, observations were made of the water storage containers, a mixture of storage containers were being used; many (56%) of the households had narrow mouthed containers, 19% had wide mouthed and 25% had both types of containers. The opening of all the containers was covered in 100% of the cases. The research teams judged the water storage containers to be clean in 100% of the households.

6.4 Users' feedback on the RO plant

After the RO filtration plant has been used for 8 months by the beneficiaries, DACAAR health promotor couples interviewed the 16 households using a questionnaire (see Annex-9). The results were as follows:

6.4.1 Findings

- 100% of the interviewed households were satisfied with the solar-powered RO filtration plant.
- All households use the treated water only for drinking and cooking.

- All households receive on average 50 litres of water (minimum 30 litres, maximum 60 litres) every day.
- The treated water is not available all the day and released at the end of the day for 10 to 15 minutes.
- All the water meters at the households were functional and readings are recorded on a monthly basis by the operator of the WMC.
- 100% of the interviewed households liked the filtered water because it is tasty, fresh, clean and without smell.
- 100% of the interviewed households said that the RO plant provides enough water for drinking and cooking but not enough for washing hands, bathing and washing clothes.
- 100% of the interviewed households said that they had no problems with the RO plant since they have been using it for the last 8 months.
- 100% of the interviewed households said that since they have started using the filtered water from the RO plant (8 months ago), their families' health has improved as they noticed a decrease in waterborne diseases.
- 100% of the interviewed households said that they pay water bills between 120 and 400 AFN monthly, depending on their individual consumption of water.
- 100% of the interviewed households had safe water storages at home from which 56% were narrow mouthed containers, 19% wide mouthed containers and 25% had both types. All the storage containers appeared to be clean, had a lid or were covered with a lid and were kept at a suitable place inside the house.

6.5 WMC feedback on the RO plant

DACAAR WET Centre interviewed members of the WMC, staff of the DACAAR Central Regional Office and from the Technical Unit by using a questionnaire (Annex- 7 & 8).

6.5.1 **Findings** (from observation and interview of the WMC and DACAAR staff)

- The community with support of DACAAR, established a Water Management Committee (WMC) consisting of one leader and 8 members.
- The RO filtration project was handed over properly. The handover documents and O&M agreements were available.
- The community has a trained local mechanic/operator who received training and the required tool kit and consumables (e.g. chemicals) for the O&M of the system.
- Two guards were selected among the community.
- The WMC managing the system properly, weekly records the O&M of the system, conducts monthly readings of users' water meters and collects 70 AFN per cubic meter of water. However, there was no O&M plan available once the life cycle of the system has been completed, specifically, the cost for replacing the RO membrane filter, sand filter, carbon filter and solar panels.
- The WMC keeps the collected money from the users for O&M of the system but the WMC has no bank account set up.
- The mechanic operates the system properly and cleans the solar panels regularly and the guards safeguard the system.

- The mechanic (operator) is paid 10,000 AFN per month; and the two guards are paid 7,000 AFN per month each.
- The water users support the WMC and regularly pay for operation and maintenance, however, some users do not pay on time.
- The required consumables (chemicals, replaceable parts, etc.) for the system are available in the local market in Kabul but the quality is low compared to the original parts provided by the contractor. Sodium Hydroxide (NaOH) is used for Boron treatment, antiscalant chemical is used for RO membrane filter back wash and minerals are mixed in the filtered water for re-mineralization. The detail of costs for the required consumables/ chemicals and O&M are available in Annex-5

6.5.2 WET Centre findings / recommendations on the RO plant

- The filtering efficiency of the RO plant is found to be around 50%. This means that 50% of the source water is filtered and 50% is rejected/wasted.
- The RO plant is operated for 6 hours in winter and 8 hours in summer and provides around 9.81 m^3 filtered water per day in winter and around 12.36 m^3 per day in summer. This means that the RO plant can provide around 4.6 litre/person in winter and around 5.8 litre/person in summer for 2,135 users.
- The control unit of the system (well probe sensor and float switch) is not working properly due the long distance between the control unit and the system, so it is recommended to shift the solar panels and control unit from the Mosque (Masjed) to top of the reservoirs or close to the system to reduce the cable length and to prevent electricity losses due to the long length of the cable.

6.5.3 WMC and the users' comments / suggestions

- WMC requested to connect the RO system with the city power, so the plant can provide sufficient water in winter and cloudy seasons as well.
- One exhaust fan is required for RO filtration room.
- A room and a bathroom inside the boundary of the RO system is required for the mechanic and for the guards. This was not considered in the project design.
- A mesh wire fence is required around the RO filter canopy/room made of glasses for safety, to prevent any damage.
- The water distribution is not uniform; some families receive less water due to the lower pressure in their house connection pipes.
- As the control unit has been installed far from the system, the controllers (well probe sensor and float switch) are therefore not working properly due to the long distance of the control unit with the system. So it is recommended to shift the solar panels and control unit close to the system.
- According to the community members, there is less saline water at 70 m depth but the tube well is 50 m deep and contains very salty water, so the community requested a tube well that is 70 or 80 m deep.

7. Conclusion

The efficiency of the solar-powered RO filtration system was very high: 97% in removal of salinity, 100% in removal of bacteria, and above 90% in removal of other chemical contaminants from the source water.

The removal efficiency of the RO plan was low in boron removal. Therefore, sodium hydroxide is mixed with the raw water in order to reduce the boron through ionization before it is filtered.

According to the installed RO plant specification, it was supposed to filter 5 m^3 per hour of raw water, however, it was found that the plant can filter only 3.4 m^3 of raw water per hour in winter and 4.3 m^3 in summer.

Based on the users' feedback and the measurements, the RO plant provides sufficient water to the users for drinking and cooking. Some users receive more water than others due to differences in the pressure at the house connection pipes. The issue of equal pressure at house connections to be considered in such designs in the future.

The established WMC is managing the O&M of the system. The amount of fees collected from the users are enough for the operation of the system, however, a saving plan for sustainable maintenance (life cycle cost saving) of the system is recommended that is not considered.

8. Recommendations

- The installed RO plant is effective in removing salts and minerals but not effective in sufficiently removing boron and therefore currently essential chemicals are used for boron removal, re-mineralization of filtered water and membrane filter cleaning. A simpler method is needed in order for such project to be sustainable and for the communities to handle the water cleaning without support. It is therefore recommended to select RO plants with limited or no chemical use or to investigate a two-membrane RO-system that can secure the right boron levels.

- Enhance the capacity of DACAAR's technical team about RO treatment technologies, so they can identify more suitable and better RO systems for such projects in the future.

- The solar panels should be shifted from the mosque (masjed) closer to the system to prevent electricity losses and increase the filtration discharge of the RO system.

- The system's control unit should be installed close to the system as currently, it is installed too far away from the tube well and as a result, the controllers (well probe sensor and float switch) are not working properly because of the long distance of control unit with the system.

9. List of Annexes

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Annex-2 RO Plant Accessories and Operation
Annex-3 Tube well detail
Annex-4 Cost of the RO filtration system
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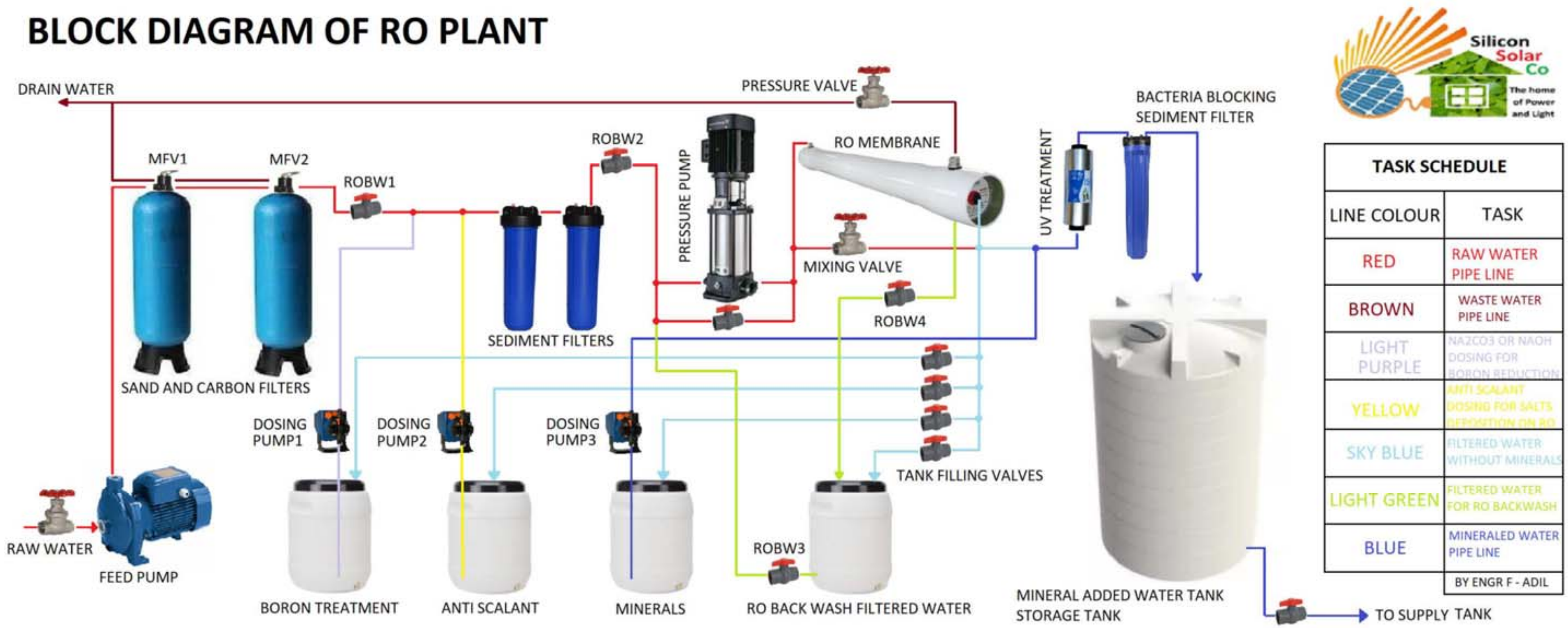
Annex-6 Water quality test results of Qala-e-Gulbaz RO Plant
Annex-7 Questionnaire for info collection on the RO Plant
Annex-8 Questionnaire for info collection on O&M of the RO Plant
Annex-9 Questionnaire for info collection from users on the RO plant drinking water

9.1 Annex-1 Silicon Solar Company RO plant Block diagram labeled



9.2 Annex-2 RO Plant Accessories and Operation

PLANT ACCESSORIES

- PLANT SIZE 10000 GPD
- SOLAR ARRAY SIZE 9.5KW
- INVERTERS 5.5KW TWO PIECES, ONE FOR PRESSURE PUMP AND SECOND FOR REST PUMPS

RO PLANT OPERATION

1. Open RAW water Valve
2. Switch ON the main breaker of INVERTER2 and Turn ON INVERTER2 from RO plant panel
3. Put MFV1 (multifunction Valve of Sand Filter) Valve on backwash. Turn ON FEED PUMP, keep backwashing for 10 minutes after this turn OFF FEED PUMP and put MFV1 Valve back on filter. Now put MFV2 on backwash and turn ON FEED PUMP, keep backwashing for 10 minutes and then turn OFF FEED PUMP and put Valve back on filter. This is done once, early in the morning
4. Check ROBW1 and ROBW2 (RO back wash Valve) for to be opened
5. Fully open PRESSURE Valve turn ON FEED PUMP and switch ON main breaker of INVERTER1 check capacity of WASTE water in indicator. Turn ON Anti Scalant DOSING PUMP2 from panel. Turn ON PRESSURE PUMP from INVERTER1 ON button, WASTE water capacity will rise.
6. Slowly close PRESSURE VALVE and check filtered water capacity in indicator, keep on closing till it reaches 7 GPM check water production in STORAGE TANK. Turn ON Minerals DOSING PUMP3, Boron Treatment DOSING PUMP1 and UV light form Panel. Check TDS if it is less than the required increase Dosing level of DOSING PUMP3, if greater than required decrease dosing level. If necessary TDS can be adjusted from MIXING VALVE by slightly changing it
7. Plant will start production on its normal capacity and Mineral added water will store on storage tank
8. When storage tank is full plant will automatically turn ON the pump inside storage tank and will start filling the supply tank (20000 liter tank). When storage tank gets empty plant will automatically turn OFF the pump inside storage tank
9. If the power is not sufficient to turn all the pumps on time then turn OFF whole plant and Only start the pump inside storage tank from panel and when storage tanks gets empty start the plant again
10. At 4:00 PM turn OFF the plant and start back washing RO membrane as
11. Fully open PRESSURE VALVE. Close ROBW1 and ROBW2. Open ROBW3 and ROBW4. Turn OFF all pumps and turn ON PRESSURE pump Keep backwashing for 10 minutes and turn OFF the plant
12. Put all valves back on its places for tomorrow use.

NOTE: RO should be operated on its normal capacity i.e. 7GPM it can be increased but will ruin membrane's life!

When there is not enough sunlight and filtered water is needed plant must be kept on small capacity i.e. 2 – 4 GPM

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9. 3 Annex-3: Tube well detail

Specification of Water Source (Tube Well)		
1	Depth of the tube well	(50) m
2	Depth of Static Water Level (SWL) and Dynamic Water Level (DWL)	SWL = (9.5) m DWL = (11.82) m
3	Safe yield (discharge) of the tube well	(174) Litre/min or (2.9) Litre / Sec
4	Depth of the DC solar submersible pump installation in the tube well	(42) m
5	Is the tube well providing the demanded amount of water to the RO plant?	Yes
6	Diameter of drilling, and casing/filter pipe installed in the tube well	Boring/drilling diameter = (14) inch Casing/filter pipe diameter = (8) inch
7	Type of casing/filter pipes used in the tube well	PVC, Class-E

9.4 Annex-4 Cost of Solar-powered RO filtration Water Supply System

78 AFN = I USD

S/N	Item Description	Unit	Quantity	Unit Cost (AFN)	Total Cost	
					AFN	USD
Solar-powered RO filtration Plant						
1	Complete set of RO water filter system that can filter 5m3/hour raw water	No	1	1,550,400	1,550,400	19,877
2	Solar panels (Linuo, made in Germany) to run the RO filter	No	1	697,500	697,500	8,942
3	Power cables, switches, sockets, main switch, fittings and other required accessories	Lump-sum	1	80,000	80,000	1,026
4	Construction of one canopy for the RO plant	Lump-sum	1	200,000	200,000	2,564
5	Installation cost		1	20,000	20,000	256
				Sub-total	**2,547,900**	**32,665**
Two RCC Elevated Reservoirs, PE Piped Network & Well Construction						
1	10m3 RCC reservoir (6m elevated) + 20m3 reservoir (12m elevated) + PE piped network + well drilling and construction	Lump-sum	1	10,698,452	10,698,452	137,160
				Sub-total	**10,698,452**	**137,160**
	Total				**13,246,352**	**169,825**

Cost per capita (USD) = 79.54

9.5 Annex-5 Cost of the required consumables and O&M of the RO Plant

DACAAR Solar-powered Filter (SN:SWF10KGPD9K45)
Required Consumables / Raw Materials Detail / O&M

S/N	Description	Span (month)	Unit	Quantity	Unit Cost (AFS)	Sub-total Cost (AFS)	Total Cost/year (AFS)	Total Cost/Month (AFS)
Consumables & Raw Materials Cost								
1	Sediment filter 5 micron	12	No	20	800	16,000	16,000	1,333
2	sediment filter 1 micron	12	No	10	400	4,000	4,000	333
3	Antiscallant	12	Liter	32	800	25,600	25,600	2,133
4	Minerals	12	Liter	180	600	108,000	108,000	9,000
5	Sodium carbonate	6	Kg	48	38	1,824	3,648	304
6	Sodium Hydroxide	3	Kg	25	64	1,600	6,400	533
7	Sand and Carbon filter	12	No	1	5,000	5,000	5,000	416.67
8	RO membrane filter	24	No	1	150,000	150,000	150,000	12,500.00
Sub-total							**318,648**	**26,554**
Operation & Maintenance Cost								
9	Minor repair	2	No	12	1,000	24,000	24,000	2,000
10	Operator wages	12	month	1	10,000	120,000	120,000	10,000.00
11	Guard wages	12	month	2	7,000	168,000	168,000	14,000.00
12								
13								
Sub-total							**312,000**	**26,000**
Total Cost							**630,648**	**52,554**

9.6 Annex-6 WQT results of Qala-e-Gulbaz RO Plant

Annex-6 WQT results of Qala-e-Gulbaz RO Plant

Source water

		WHO recc	ANSA recc	Comments	1	2	3	4	5	6	7	8
Physical parameters		**WHO recc**	**ANSA recc**		16-Apr-19	16-Sep-19	24-Sep-19	02-Oct-19	10-Oct-19	16-Oct-19	28-Oct-19	13-Nov-19
EC		*1500*	*3000*		6480	5380	5330	5250	5400	5300	5400	5380
TDS *		*1000*	*2000*	** From Conductivity*	4458	3701	3667	3612	3715	3646	3715	3701
ORP					237	213	167	161	110	118	125	152
Turbidity		*5*	*5*	*< 1 for chlorination*	3.39	2.48	0.53	0.58	0.55	0.58	0.52	0.66
pH		*6.5 - 8*	*6.5 - 8.5*	*< 8 for chlorination*	7.75	8.13	7.89	7.89	8	8	8	8
°T		-	-		18.5	19.1	17.9	20.7	22.5	23	23	16.4
Chemical determination			*Spectrophotometer Palintest 8000*									
Anions		**WHO recc**	**ANSA recc**	**Comments**	16-Apr-19	16-Sep-19	24-Sep-19	02-Oct-19	10-Oct-19	16-Oct-19	28-Oct-19	13-Nov-19
Total Alkalinity	(as $CaCO_3$)	-	-		310							
Alkalinity P	(as $CaCO_3$)	-	-		10							
Alkalinity M	(as $CaCO_3$)	-	-		360							
Bicarbonate	HCO_3^-	-	-		340							
Carbonate	CO_3^{2-}	-	-		20							
Hydroxide	OH^-	-	-		0							
Chloride	Cl^-	*250*	250	*Taste*	1125							
Sulphate	SO_4^{2-}	*250*	250	*Taste*	1317							
Sulphite	SO_3^{2-}	-	-		2							
Sulphide	S^{2-}	-	-		0.02							
Fluoride	F^-	1.5	1.5	Fluorosis	5.2							
Nitrate	NO_3^-	50	50	Blue baby syndrom	284							
Nitrite	NO_2^-	0.2 - 3	3	long - short term expositure	0.322							
Phosphate	PO_4^{3-}	-	-		0.15							
Boron	B	2.4	2.4	Testicular lesions	6.63	6.2	6	6.25	6.2	6.24	6.12	6.5
Bromide	Br^-	-	-		0.38							
Cations		**WHO recc**	**ANSA recc**		16-Apr-19	16-Sep-19	24-Sep-19	02-Oct-19	10-Oct-19	17-Oct-19	28-Oct-19	13-Nov-19
Total Hardness	(as $CaCO_3$)	*300*	500	*Taste and incrustation*	850							
Calcium Hardn	(as $CaCO_3$)	-	-		140							
Sodium	Na^+	*200*	200	*Taste*	1267							
Potassium	K^+	-	-		10							
Calcium	Ca^{2+}	-	-		56							
Chromium	$Cr^{6+}{}_{\_diss.}$	0.05	0.05	Cancerogenic	0.02							
Magnesium	Mg^{2+}	-	-		155							
Ammonium	NH_4^+	*1.5 - 35*		*Odour - taste treshold*	0.28							
Manganese	Mn^{2+}	0.4		*> 0.1 affects taste and stains laundary*	0.017							
Copper	$Cu_{\_total}$	*2*	2	*Taste*	0.22							
Aluminum	$Al_{\_total}$	-	0.2		0.01							
Total iron	Fe^{2+} and Fe^{3}	*0.3*	0.3	*Taste and odour*	0.14							
Total Arsenic	As $^{3+}$ and As	0.01	0.05		0.015							
Other components		**WHO recc**	**ANSA recc**									
Silica	SiO_2	-	-		28							
Hydrogen Sulp	H_2S	*0.100*	-	*Taste and odour*	0.0212							
Residual Chlori	Cl_2	0.2-0.5	0.2-0.5		0							
Bacteriological Determination												
		WHO recc	**ANSA recc**									
H_2S determination		N	-									
Total Coliforms		0	-	*(Incubation time: 24 hrs @ 37°)*								
Fecal coliforms (e-Coli)		0	0	*(Incubation time: 24 hrs @ 44°)*	0	0	0	0	12	55	0	

Filtered Water (1–11)

	1	2	3	4	5	6	7	8	9	10	11
Physical parameters	21-Apr-19	13-May-19	15-May-19	20-May-19	29-May-19	30-May-19		11-Jun-19			
EC	310	99	204	219				94	82	83	84
TDS *	213	68	140	151				65	56	57	58
ORP	242	222	223	190				179	167	107	96
Turbidity	0.84	0.4	0.21	0.66				0.5	0.05	0.06	0.11
pH	7.75	8.5	8.47	7.9	7.14	9	7.98	7.98	8	8.29	8.57
°T	20.3	20	16.5	18.3							
Anions	21-Apr-19	13-May-19	15-May-19	20-May-19	29-May-19	30-May-19		11-Jun-19			
Total Alkalinity	40	15	5	10							
Alkalinity P	5	5	15	15							
Alkalinity M	55	20	20	35							
Bicarbonate	45	10	0	5							
Carbonate	10	10	10	30							
Hydroxide	0	0	10	0							
Chloride	119	20.5	42	47							
Sulphate	53	4	1	24							
Sulphite	7	7	6	6							
Sulphide	0	0	0	0.01							
Fluoride	0.1	0.3	0.27	0.34							
Nitrate	4.16	4.96	7	9.12							
Nitrite	0.001	0.013	0.007	0.007							
Phosphate	0.05	0.05	0.01	0.01							
Boron	2.49	3.8	3.3	2.5	2.6	2.9	4.4	3	2.3	1.75	1.4
Bromide	0.27	0.24	0.12	0.23							
Cations	21-Apr-19	13-May-19	15-May-19	20-May-19							
Total Hardness	115	30	35	30							
Calcium Hardn	58	3	13	1							
Sodium	7	35	50	48							
Potassium	1.2	1.7	0	1.7							
Calcium	23	1	5	0							
Chromium	0.01	0.02	0.02	0.02							
Magnesium	55	1.6	3.1	16							
Ammonium	0	0	0	0							
Manganese	0	0	0	0							
Copper	0.08	0.1	0.18	0.12							
Aluminum	0	0.03	0.05	0.02							
Total iron	0.02	0.05	0.06	0.05							
Total Arsenic	0	0	0	0							
Silica	6.5	0.36	0.38	0.34							
Hydrogen Sulp	0	0	0	0.0106							
Residual Chlori	0	0	0	0							
Fecal coliforms (e-Coli)	0	0	0	0							

Filtered Water (12–23)

	12	13	14	15	16	17	18	19	20	21	22	23
Physical parameters	16-Jun-19	27-Jun-19	08-Jul-19	21-Jul-19	04-Aug-19	16-Sep-19	24-Sep-19	02-Oct-19	10-Oct-19	16-Oct-19	28-Oct-19	13-Nov-19
EC	79	289	198	84	136	164	143	133	219	245	211	243
TDS *	54	190	136	58	54	113	98	92	150	167	145	167
ORP	216	188	164	124	203	196	187	193	144	155	155	145
Turbidity	0.65	0.52	1.03	0.58	0.54	0.25	0.22	0.21	0.24	0.22	0.23	0.57
pH	6.5	8.15	8.25	6.31	8	7.25	6.7	6.93	7.12	7.48	7.54	8.5
°T	19.9		19.3	21.1	19.6	22.3	17.9	18.9	18	19.5	18.3	17.2
Anions	16-Jun-19	27-Jun-19	08-Jul-19	21-Jul-19	04-Aug-19	16-Sep-19	24-Sep-19	02-Oct-19	10-Oct-19	16-Oct-19	28-Oct-19	13-Nov-19
Total Alkalinity	60		20	45	15							
Alkalinity P	20		5	10	2							
Alkalinity M	100		30	60	20							
Bicarbonate	60		20	40	16							
Carbonate	40		10	20	4							
Hydroxide	0				0							
Chloride	104		44	32	31							
Sulphate	4		19	6	29							
Sulphite	12		7	5	2							
Sulphide	0		0	0.01	0							
Fluoride	0.54		0.6	0.18	0.09							
Nitrate	8.16		9.78	8.04	7.18							
Nitrite	0.002		0.002	0.001	0.007							
Phosphate	0.01		0.02	0.06	0.02							
Boron	4.94	2.1	2.4	2.2	2.1	3.28	2.4	2.4	3.3	3.9	1.7	3.4
Bromide	0.56		0.42	0.45	0.22							
Cations	16-Jun-19	27-Jun-19	08-Jul-19	21-Jul-19	04-Aug-19	16-Sep-19	24-Sep-19	02-Oct-19	10-Oct-19	17-Oct-19	28-Oct-19	13-Nov-19
Total Hardness	60		20	20	20							
Calcium Hardn	24		0	0	2							
Sodium	90		59	56	37							
Potassium	2.3		1.8	1.6	0.2							
Calcium	10		0	0	1							
Chromium	0.02		0.01	0.02	0							
Magnesium	22		3	4	7							
Ammonium	0		0	0	0							
Manganese	0		0	0	0.002							
Copper	0.03		0.38	0.2	0.17							
Aluminum	0		0	0.03	0.01							
Total iron	0.04		0.04	0.01	0.01							
Total Arsenic	0		0	0	0							
Silica	4.4		4	6.5	2.5							
Hydrogen Sulp	0		0	0.0106	0							
Residual Chlori	0		0	0	0							
Fecal coliforms (e-Coli)	0		0	0	0	0	0	0	0	0	0	0

9.7 Annex-7: Questionnaire for Gathering Info on Qala-e-Gulbaz Solar-powered RO filtration Water Supply System

1 - Project General Information			
Province:	Kabul	Project Starting Date:	
District:	19	Project completion date:	
Village Name:	Qala-e-Gulbaz	Project operation starting date:	
No. of Designed Beneficiary	( ) Household ( ) Family ( ) person	Interview Date:	
No. of Current Beneficiary	( ) Household ( ) Family ( ) person	Interviewee Name:	
Designed Water Demand:	( ) litre/person/day ( ) m3 /day	Interviewer Name:	

2. Quality and Quantity of RO Plant Filtered Water			Comments
1	How much is the flow rate of filtered water from the RO plant?	1. ( ) Liter/hour 2. ( ) m3/day	
2	How much is the flow rate of Raw water to the RO plant?	3. ( ) Liter/hour 4. ( ) m3/day	
3	Is physical quality of the filtered water is according to WHO recommendation and ANDWQS?	1. Yes 2. No	
4	Is the bacteriological quality of the filtered water is according to WHO recommendation and ANDWQ.	1. Yes 2. No	
5	Is there any other chemical found above the limit in the filtered water?	1. Yes (specify); 2. No	
6	How much is water demand of the community (Qala-e-Gulbaz Village) for 24 hours?	( ) litre/person/day ( ) m3 /day	
7	How many hours the RO plant operated each day?	( ) hrs	
8	How much water is filtered each day?	( )m3	
9	Is the system providing water according to the demanded of the community?	1. Yes 2. No	
Interviewer's Comments:			
Other Comments:			

3- Specification of Water Source (Tube Well)		
1	How many meter is depth of the tube well?	( ) m
2	How many meter is the depth of Static Water Level (SWL) and Dynamic Water Level (DWL)?	SWL = ( ) m DWL = ( ) m
3	How much is the safe yield (discharge) of the tube well?	= ( ) Litre/min or = ( ) Litre / Sec
4	At what depth the DC solar submersible pump is installed in the well?	= ( ) m
5	Is the tube well providing the demanded amount of water to the Ro plant?	1. Yes 2. No
6	What is the boring and casing/filter diameter installed in the tube well?	Boring/drilling diameter = ( ) inch Casing/filter pipe diameter = ( ) inch
7	What type of casing/filter pipes are used in the tube well?	1. PE 2. Iron
Interviewer's Comments:		
Other Comments:		

9.8 Annex-8: Questionnaire for Gathering Info on O&M of Qala-e-Gulbaz Solar-powered RO filtration Water Supply System

1- Water Management Committee (WMC) Detail			
S/N	**Name**	**Position in WMC**	**Role/responsibility in WMC**
1			
2			
3			
4			
5			
6			
7			
8			
9			
Interviewer's Comments:			
Other Comments:			

2- Operation and Maintenance (WMC Interview)		**Yes**	**No**	**Comments**
1	Is the RO filtration water supply system have a trained local operator/plumber?			
2	Are the tools for the O&M provided to the plumber/operator?			
3	Is the operator operating the system properly?			
4	Is the operator guarding the solar-powered RO system?			
5	Is the operator keeping the panels clean?			
6	Is the WMC established?			
7	Is the WMC managing the system properly?			
8	Is the WMC has a continuous O&M plan for the system?			

9	Is there any periodic recording for O&M?			
10	Is there any periodic recording for house connection water meters?			
11	Are the user groups supporting the WMC and regularly pay money for system operation and maintenance?			
12	Is the WMC regularly collecting the money from users for the O&M of the system? (how much per litre or m3)			
13	Is the wages of the RO system operator paid on time (how much/month)?			
14	Is the WMC has a saving for O&M of the system?			
15	Is the project handed over properly (the handover documents and O&M agreements available)?			
Interviewer's Comments:				
Other Comments:				

3- Consumables and Replaceable Filters Required for Operation and Maintenance			
S/N	**Description**	**Name & Amount**	**Cost**
1	What consumable/ chemicals are used in the system (per month or year)?		
2	What are the required replaceable parts (filter) in the system (per month or year)?		
3	Are the required consumable/chemicals for the system operation is available in local market (Kabul)?		
4	Are the required replaceable part (filters) for the system maintenance available in local market (Kabul)? If not where?		
Interviewer's Comments:			
Other Comments:			

9.9 Annex-9 Qala-e-Gulbaz Solar-powered RO filtration Water Supply System Evaluation Questionnaire

1. Demography	
Number of people in family	
Number of children less than 1 year	
Number of children 1-4 years	
Number of children 5-14 years	
Number of adult men	
Number of adult women	
Who is the head of the family	1. Male 2. Female
Interviewer's Comments:	
Other Comments:	

2. Water Storage			**Comments**
1	Are the water storage containers present?	**1.** Yes **2.** No	
2	What type of containers are they using?	1. Narrow mouthed 2. Wide mouthed 3. Both 4. Others (specify)	
3	Are the storage container covered or with lid?	**1.** All **2.** None **3.** Some	
4	Are the storage containers placed at suitable place at house?	1. Yes 2. No	
5	Do the containers appear clean?	3. Yes 4. No	
Interviewer's Comments:			
Other Comments:			

3.	Water Questions		Comments
1	Are you happy because of this project? (considering quality, quantity and access)	1. Yes 2. No	
2	What are all the purposes you use the RO filtered water for?	1. Drinking 2. Food preparation 3. Bathing 4. Hand washing 5. Other (Specify)	
3	How much water do you use every day from the RO plant?	( ) litre	
4	Is water available all the times or whenever needed?	1. Yes 2. No	
5	How long have you been using water from the RO plant?	( ) Months	
6	Is your water meter functional?	1. Yes 2. No	
7	Is your water meter readings recorded by the WMC/operator?	1. Yes 2. No	
8	Are the water user groups preventing the water wastage?	1. Yes 2. No	
Interviewer’s Comments:			
Other Comments:			

4.	User's Perceptions		Comments
1	Do you like the RO plant filtered water?	1. Yes, because: 2. No, because:	
2	How is taste of the RO plant filtered water?	1. Tasty/fresh 2. saline 3. Other (specify)	
3	How is smell of the RO plant filtered water?	1. No smell 2. Smell 3. Other (specify)	
4	How is appearance of RO plant filtered water?	1. Clean 2. Turbid 3. Other (specify)	
5	Does the RO plant provide enough water for the entire family?	1. Yes 2. No	

6	Have you had problem with the RO plant filtered water?	1. No 2. Yes, specify:	
7	Since you started using the RO filtered water, do your family's health has been improved, stayed the same or become worse?	1. Better 2. Worse 3. About the same	
8	Do you pay money/bill for the water?	1. No (Why): 2. If yes, how much per month	
Interviewer's Comments:			
Other Comments:			