Standard Operating Procedure for

Advance Reverse Osmosis (ARO)

Dushtha Shasthya Kendra (DSK):

Gender-Sensitive Humanitarian Assistance in WASH for the Rohingya Refugee and Host Communities in Teknaf, Cox's Bazar. BGD 1060, Camp-26.

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1.1 Introduction:

The availability of clean and safe drinking water is a major concern globally, especially in Bangladesh, where various environmental factors contribute to water contamination. Waterborne diseases, lack of proper water treatment, chemical pollution, and natural disasters make clean water access even more challenging. The availability of safe drinking water is a fundamental necessity for human survival, and ensuring its quality is essential.

Rohingya refugees in Bangladesh mostly refer to forcibly displaced Myanmar nationals from Myanmar who are living in Bangladesh. From August 2017 the number of refugees in Bangladesh

has increased rapidly due to ethnic and religious persecution in Myanmar. According to the UN Refugee Agency-UNHCR, more than 723,000 Rohingya have come to Bangladesh since 25 August 2017. Overcrowding from this population boom at Bangladesh's Rohingya refugee camps has placed a strain on its infrastructure. The refugees lack access to services, education, food, clean water, and proper sanitation; they were also vulnerable to natural disasters and infectious disease transmission.

Especially, due to much more water scarcity in the Teknaf region, the camp management at the Teknaf region had been facing more challenges to ensure safe drinking and useable water for domestic purposes at camp level. The Teknaf region is surrounded by the Bay of Bengal and Naf River. Therefore, some area's soil is in rock condition where drilling is not easier and maximum underground water aquifers are mixed with the salt water. There are few pocket aquifers with very limited quantities of sweet water, but it is very uncertain to get these. Mainly in the dry season water level totally falls and it becomes very challenging to get water from the pocket aquifers of sweet water. Due to this, there are only two sources for sweet water- (i) Spring-water & (ii) Rainwater. But in Teknaf there are insufficient natural reservoirs to preserve the rainwater. On the other hand, the Naf River water is also not usable due to high salinity as it is directly connected with the Bay of Bengal. For this reason, the Rohingya and host community people of Teknaf region were facing a severe water crisis.

By considering these problems DSK started working in supplying safe water for the Rohingya and adjacent host community people through ARO Plant which funded by Welthungerhilfe & German Federal Foreign Office from January 2025.

To maintain safe drinking water standards, proper treatment methods must be followed, including filtration, disinfection, and the removal of harmful contaminants. The implementation of effective water treatment measures is crucial for ensuring public health, especially in urban areas where the population is dense, and the demand for clean water is high. The importance of using modern water purification technologies, combined with strict quality control measures, cannot be overstated.

1.2 Objective:

The objective of this Standard Operating Procedure (SOP) is to establish standardized and safe operating guidelines for the Reverse Osmosis (RO) plant to ensure:

- **Consistent Production of High-Quality Treated Water:** Ensure the RO plant consistently produces treated water that meets predefined quality standards suitable for industrial, domestic, or process requirements.
- **Safe and Efficient Operation:** Define the operational parameters, safety measures, and procedures to be followed by plant personnel to maintain safe and efficient operation of the system.
- **Optimization of Plant Performance:** Optimize the operational efficiency of the RO system, including membrane performance, recovery rate, and energy consumption.
- **Prevention of System Failures and Downtime:** Prevent unexpected breakdowns or failures through scheduled monitoring, maintenance, and timely corrective actions.
- **Regulatory and Environmental Compliance:** Ensure that the RO plant operations comply with local and international environmental, health, and safety regulations.
- **Documentation and Record Keeping:** Standardize the documentation process to maintain detailed records of plant operations, maintenance activities, and water quality analysis for audits and performance tracking.
- **Training and Skill Development:** Provide a reference document for training new operators and enhancing the skills of existing personnel.

1.3 Advance Reverse Osmosis (ARO) and Its Purpose

Reverse Osmosis (a water Treatment system) provides a comprehensive water treatment solution that ensures the removal of contaminants, making water safe for consumption. The system includes advanced purification techniques that eliminate harmful substances, bacteria, and chemical pollutants from water sources.

Key Features of ARO Water Purification System:

- Removes biological contaminants from water
- Reduces chemical pollutants and heavy metals
- Ensures proper filtration and disinfection processes
- Enhances water clarity and quality

- Maintains essential mineral balance in treated water

ARO ensures water purification by eliminating the following contaminants:

- Bacteria and viruses (>1 mg/L)
- Heavy metals such as lead (>0.001 mg/L) and arsenic (>0.005 mg/L)
- Harmful chemicals like chlorine and fluorides (>0.05 mg/L)
- Industrial pollutants and sediments (>600 mg/L)
- Organic compounds and pesticides (>10 mg/L)

By utilizing ARO, communities can access clean and safe drinking water, reducing health risks and improving overall well-being.

1.4 General Information

Year of Established:	: 23 October-2019.
ARO ID:	: WHH-DSK- ARO-2019-10-C26-01
Location	: Shal Bagan, Naya Para, Teknaf, Cox's Bazar, Bangladesh.
Area of Service Delivery:	: Camp-26, (Sub Block G-3, G-4, G-5, G-6, F-8, F-9, F-10, and H-10 & Host Community
GPS Location:	: Latitude-20.95098, Longitude-92.25732
Total Area of ARO Plant:	: 1625 m2
Treatment Technology:	: Advance Reverse Osmosis (ARO)
Treated Water Reservoir Capacity:	: 95 m3
# of Population Covered:	: 7259 (Rohingya-4900 & Host Community-2250)
# of ARO Unit	: 4 Unit
Treatment Capacity of the ARO:	: 120m3/day
# of Tap stand:	: 16
ARO Unit Capacity:	: 3.2 to 3.8 m3/ Hour/Unit
Test Conducted After Treatment:	: pH, Salinity, E. coli, FRC, Turbidity, TDS, EC, FC
Pretreatment Storage Chamber Capacity:	: 1300 m3
Length of Pipeline Network:	: 7500 meters
Electricity Load Connection:	: 150 KVA
Generator Capacity:	: 150 KVA

1.5 Technical Information

ARO specifications:

Advance Reverse Osmosis (ARO) plant in three purification capacities in four RO machine. Two are 3600 liters per hour (LPH), One is 1800 liters per hour (LPH) and last one is (600 LPH). So total Purification capacity of 9600 liters per hour. These RO machine compact, heavy duty and floor mounting. It outlines the key components, including pre-treatment 5 and 10-micron filter cartridge, High pressure pumps, RO membranes, post-treatment, and control panel. Technical specifications are provided for each component, including capacities, materials, pressures, and electrical requirements. RO unit have the Recovery: 55-60%.

RO Machine 01 & 02 specifications:

Production Flow	3.8 M3/Hr. – 3.2 M3/Hr.
Inlet TSS	Max. 50 Mg/L
Inlet Turbidity	Up To 300 NTU
Outlet Turbidity	< 2 NTU
High pressure pump	Danfoss APP 10.2
Pressure required	800-1000 PSI.
Temperature	5 - 45º Celsius
Feed Pressure	2.5 Bar To 4.8 Bar
Number of Membrane House	02
Type of Membranes House	Hollow fiber Out to In / Inside Out
Number of membranes	06
Model of Membranes	Torrey 8040
Controls	Microprocessor
Flow Monitoring	Rota meter / digital flow meters.
Pre-Treatment	Dual Media Filter
Pre filters	Bag Filters/Micron Cartridge Filteres
UF Skid	MSEP / SS
Feed & Backwash Pumps	Manual
Air Scouring	Optional
Dosing Systems	Antiscalent Dosing
CIP System	For Cleaning of Membrane When Required And Optimum Performance
Pressure Monitoring	Pressure Transmitter/Pressure Guage

RO Machine 03 specifications:

Production Flow	1.5 M3/Hr. – 1.8 M3/Hr.
Inlet TSS	Max. 50 Mg/L
Inlet Turbidity	Up To 300 NTU
Outlet Turbidity	< 1 NTU
High pressure pump	Cat Pump (35 Plunger Pump)
Pressure required	600-800 PSI.
Temperature	5 - 45º Celsius
Feed Pressure	2.5 Bar To 4.8 Bar
Number of Membrane House	03
Type of Membranes House	Hollow fiber Out to In / Inside Out
Number of membranes	03
Model of Membranes	Torrey 8040
Controls	Microprocessor
Flow Monitoring	Rota meter / digital flow meters.
Pre-Treatment	Dual Media Filter
Pre filters	Bag Filters/Micron Cartridge Filters
Feed & Backwash Pumps	Manual
Air Scouring	Optional
Dosing Systems	Antiscalent Dosing
CIP System	For Cleaning of Membrane When Required And Optimum Performance
Pressure Monitoring	Pressure Transmitter/Pressure Gauge
Number of Membrane House	03

RO Machine 04 specifications:

Production Flow	0.8 M3/Hr. – 1.0 M3/Hr.
Inlet TSS	Max. 50 Mg/L
Inlet Turbidity	Up To 300 NTU
Outlet Turbidity	< 1 NTU
High pressure pump	Cat Pump (35 Plunger Pump)
Pressure required	600-700 PSI.
Temperature	5 - 45º Celsius
Feed Pressure	2.5 Bar To 4.8 Bar
Number of Membrane House	02
Type of Membranes House	Hollow fiber Out to In / Inside Out
Number of membranes	03
Model of Membranes	Torrey 4040
Controls	Microprocessor
Flow Monitoring	Rota meter / digital flow meters.
Pre-Treatment	Dual Media Filter
Pre filters	Bag Filters/Micron Cartridge Filters
Feed & Backwash Pumps	Manual
Air Scouring	Optional
Dosing Systems	Antiscalant Dosing
CIP System	For Cleaning of Membrane When Required And Optimum Performance
Pressure Monitoring	Pressure Transmitter/Pressure Gauge

Ultra-filtration Unit specifications:

Module Type	HFU-2020AN
Model	F419070852
Number of Membrane	04
Membrane Surface Area	90 m2(969 ft)
Diameter	216 mm (8.50 inches)
Length	2,160 mm (7.087 ft.)
Weight	Full of water 92 kg & drained 49 kg.
Membrane Material	PVDF (Polyvinylidene fluoride)
Nominal Pore Size	10 microns
Turbidity	200 NTU-50 NTU
TSS	200 mgl-50 mgl
Pretreatment Filter Mesh Size	Smaller than 200-micron meter
Max. Feed Water Flow	15 m3/h (66 gpm)

Max. Backwash Flow	16.8 m3/h (74 gpm)
Filtration Method	Outside to end, dead end
Connections	Housing type joint 80A top & Bottom, 65A side.
Trans-Membrane Pressure	Maximum 300 kPa (43.5 PSI) & lower the 200kPa (29.0 PSI)
Storage and Operating Temperature Range	0 – 40 degree C(32 – 104 degree F)
Operating pH Range	1 – 10

Multi-Media Vassel Filter specifications:

Vessel Type	FRP (Fiberglass Reinforced Plastic)
Diameter	18 inches
Height without base	65 inches
Capacity	4m3 liter/hour
Media Type	Multi Cartage Filter (Activated Carbon, Green Sand, Manganese).
Inlet/Outlet	2”
Application	Fe/Mn removal, Arsenic, Selenium removal,taste, odor.
Features	High filtration efficiency, Easy maintenance, Corrosion-resistant construction
Pump Support	Feed pump vertical 3hp.

Polypropylene Filter Housing:

Polypropylene filter housings are protective enclosures that hold filter cartridges, enabling the filtration of solids, sediments, and other particles from water. They are typically made from high-quality, food-grade polypropylene, ensuring durability and corrosion resistance.

RO machine high-pressure pump:

An RO machine high-pressure pump is the heart of a reverse osmosis water purification system. Its job is to take pre-filtered feed water and push it through the RO membrane at a high enough pressure to overcome osmotic pressure and force pure water (permeate) through while leaving salts, minerals, and impurities behind in the concentrate (reject) stream.

Purpose high-pressure pump:

- Increase pressure on feed water, typically from 100 psi up to 800+ psi (depending on the type of RO system—domestic, commercial, or seawater).
- Maintain steady flow and pressure so the RO membrane operates efficiently.
- Protect membrane performance and lifespan.

Type of high-pressure pump for RO Machine:

1. Positive Displacement Pumps (piston or plunger type) Cat Pump:
For RO Machine CAT Pump is a brand of positive displacement, reciprocating plunger pumps often used for high-pressure applications, including reverse osmosis treatment process. This pump can achieve very high pressures (up to 800 psi).

Key Technical Advantages:

- **Stainless steel or nickel-plated brass manifolds** for corrosion resistance.
- **Long seal life** due to precision machining and quality materials.
- **Easy maintenance** → Seal and valve kits can be replaced without full disassembly.
- **Can run continuously** (24/7) if properly cooled and lubricated.

2. APP (Axial Piston Pump) DANFOSS Pump APP10.2:
Danfoss pump in the RO world usually refers to their APP (Axial Piston Pump) series, which are widely used in seawater reverse osmosis (SWRO) and high-pressure desalination systems.

Key Technical Advantage:

- **Corrosion-resistant materials** (SS316, duplex stainless steel) to handle saline or chemically treated water.
- **Energy efficiency** (especially in large systems where pumps consume the most energy).
- **Low noise and vibration** (important in residential and small commercial systems).
- **Built-in pressure** relief or bypass valves for safety**.**

Recovery & Waste Management of RO (Reverse Osmosis) Plant:

Recovery refers to the percentage of feed water that is converted into permeate (product water)**.** It is a key performance indicator for the efficiency of the RO system, Sea Water RO (SWRO): 40% – 60%

Factors Affecting Recovery:

- **Feed Water Quality:**
  - TDS (Total Dissolved Solids)
  - Scaling potential (e.g., calcium carbonate, silica)
  - Fouling components (e.g., organics, bacteria)
- **System Design:**
  - Membrane type and configuration
  - Pretreatment efficiency
  - Pressure applied
- **Operating Conditions:**
- Temperature (warmer water increases permeability)
- pH

- Antiscalant dosage

Consequences of High Recovery:

- Increases concentration of salts in the concentrate (brine)
- Increases risk of membrane scaling and fouling
- Can reduce membrane life and performance

Improving Recovery:

- Use of antiscalants to control scaling
- Staging (multi-pass RO)
- Recirculation of concentrate
- Energy recovery devices (ERDs) in high-pressure systems
- Periodic cleaning (CIP – Clean-in-Place)

Wastewater (Reject Water / Brine) Management

Reject water typically contains concentrated salts, organics, and other contaminants removed from the feed water. Proper management is critical for environmental compliance and sustainability.

Reject Water Characteristics

- TDS: 2–3x that of feed water
- pH: Altered by chemical dosing
- Presence of scaling compounds
- Microbial content

Wastewater Management

- **Evaporation Ponds**
- Suitable for arid areas with ample land
- Low operating cost but space-intensive
- **Salt Production**
- Converts waste to solid salt and clean water
- Low capital and operating cost but space-intensive
- **Discharge to Sewer / Surface Water**
- Requires compliance with local effluent standards
- Often requires pH neutralization or dilution

Electricity Power Supply of ARO Plant

1. Power Supply

For ARO Plant power supply there required REB **Three-phase** (380–440V AC) electric line with electrical pole and for controlling this electricity one 150kv substation installed.

Main Electrical Components

Component	Power Rating (Typical)	Notes
High-pressure pump	0.5–50 HP depending on size	Main load
Feed pump	0.5–5 HP	Main load
Dosing pumps	50–150 W each	For antiscalant, chlorine
Control panel (PLC/HMI)	50–200 W	Includes contactors, relays, breakers
Miscellaneous	Variable	Lighting, small tools, etc.

Power Supply & Protection

- **Stable voltage** (use stabilizer or AVR for sensitive electronics)
- **Overload protection** (MCB/MCCB + overload relays for pumps)
- **Earth leakage protection** (RCD/ELCB for safety)
- **Surge protection** (SPD to protect PLC and sensors)

2. Motors and Pumps

- Feed Water Pump
- High-Pressure Pump (critical for membrane operation)
- Dosing Pumps (for antiscalant, chlorine, etc.)
- Backwash Pumps (for pre-filters)

All pumps must have suitable **motor starters**, **protection relays**, and **VFDs** (Variable Frequency Drives) where needed for energy efficiency and control.

3. Control Panel

- Main Control Panel (MCC/PLC-based)
- Overload Protection, MCBs, RCCBs, and Earthing
- Indicators for voltage, current, motor run/fault
- Automation: SCADA/PLC systems for larger plants with sensors (pressure, flow, conductivity)

RO Plant Operation:

Operating an RO (Reverse Osmosis) plant is a rhythmic process of monitoring pressures and water chemistry. Because RO membranes are sensitive to changes in feedwater, the daily routine is centered on "stability."

Here is a typical day-in-the-life of an RO plant and the team behind it.The Daily Schedule: Morning to Evening

1. **07:00 – 08:30 | The Morning Handover & Inspection**

The day begins with a transition from the night shift to the day shift.

- **Supply Water to field level:** Supply treated water to field level distribution tank for water distribution.
- **Raw Water Collection:** Collecting raw water from inlet pond for fillup ARO Pond.
- **Operating Machine:** Operating UF,Vessel and RO machine for water production.
- **Logbook Review:** The incoming team checks the logs for any alarms, pressure spikes, or chemical tank levels that dropped overnight.
- **Instrument Calibration:** Quick checks on pH, TDS, Turbidity, Salinity, Temperature and Conductivity meters to ensure the digital readings are accurate.

2. 09:00 – 12:00 | Sampling & Stabilization

Once the plant is confirmed stable, the focus shifts to the "health" of the water.

- **Raw Water Collection:** Collecting raw water from inlet pond for fillup ARO Pond.
- **Operating Machine:** Operating UF,Vessel and RO machine for water production.
- **Water Testing:** Taking manual samples of the rawwater, treated (clean water), and concentrate (brine).
- **SDI Testing:** Performing a **Silt Density Index (SDI)** test. This is critical—it measures how many particles are in the water before it hits the membranes.
- **Chemical Top-offs:** Refilling antiscalant or chlorine tanks as needed.

3. 12:00 – 15:00 | Data Normalization & Cleaning

Data is the only way to "see" inside an RO vessel.

- **Normalization:** Since water temperature changes throughout the day (affecting flow), operators "normalize" the data to see if a drop in flow is due to cold water or actual membrane fouling.
- **Backwashing:** If the plant uses Multi-Media Filters (MMF) as pre-treatment, the operator will trigger a backwash cycle to clean the filters.
- **15:00 – 18:00 | Maintenance & Shift Wrap-up**
- **Raw Water Collection:** Collecting raw water from inlet pond for fillup ARO Pond.
- **Operating Machine:** Operating UF,Vessel and RO machine for water production.
- **Preventative Maintenance:** Greasing pump bearings or checking the seals on the motor and pumps.
- **Inventory Check:** Ordering chemicals or filter cartridges for the upcoming week.
- **Evening Handover:** Preparing the logs for the night shift, noting any specific set-points that shouldn't be touched.

Safety Compliance of ARO Plant

- **Electrical Safety**
- Earthing: All metallic parts and panels must be properly earthed to avoid electric shocks.
- IP-Rated Enclosures: Control panels should have IP55/IP65 protection, especially in wet environments.
- Cable Management: Use cable trays, conduits, and proper insulation to prevent wear and short circuits.
- Lockout-Tagout (LOTO): Procedures during maintenance to prevent accidental energization.
- **Water & Electrical Separation**
- Install equipment in dry, ventilated areas.
- Use drip-proof or waterproof fixtures near the plant.
- Avoid routing power cables near water lines or chemical tanks.
- **Emergency & Safety Devices**
- Emergency Stop Switches (easily accessible)
- Fire Extinguishers near electrical panels (CO_2 type)
- Warning Labels & Signage
- Insulated Gloves & Safety Mats for operator use

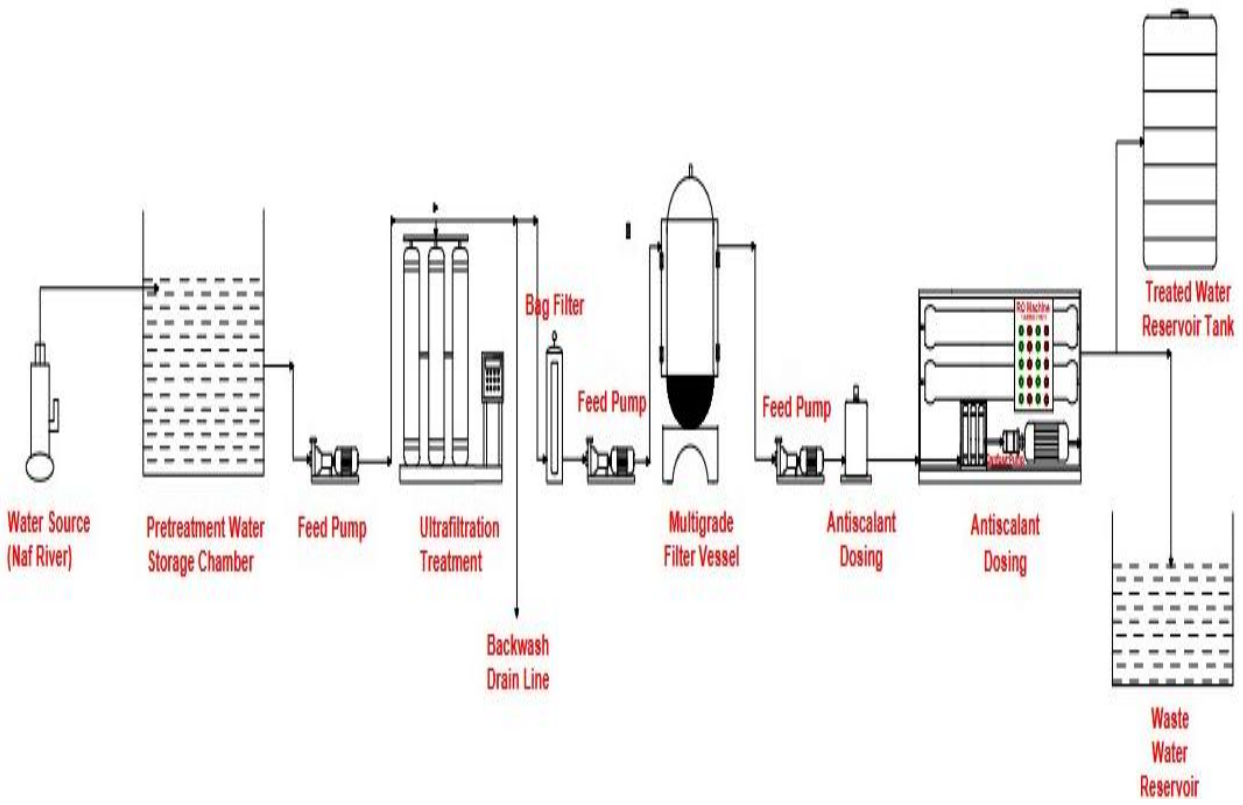
Feed water requirements:

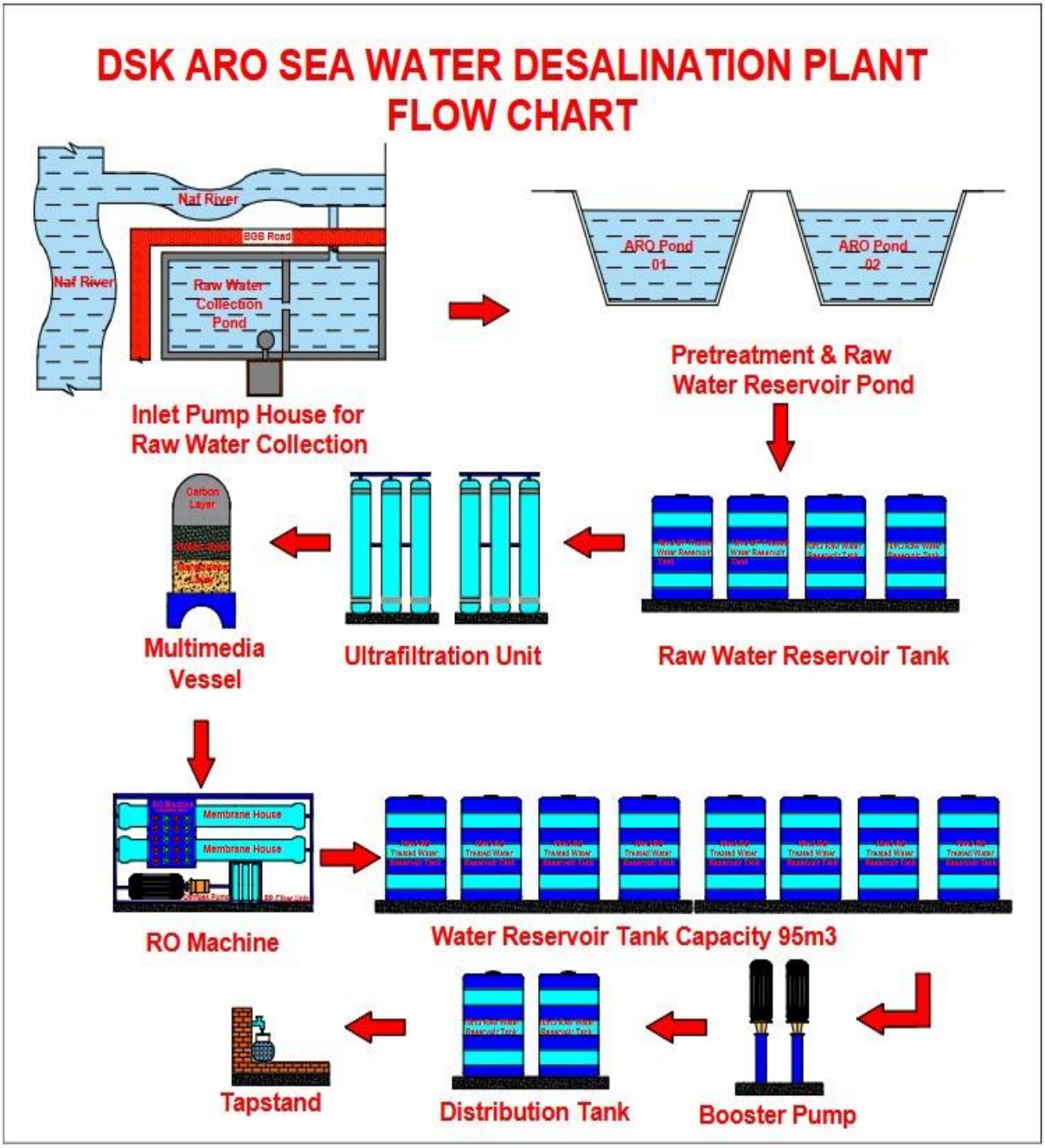
From feed water, reverse osmosis (RO) can remove up to 99 % of dissolved salts, colloids, particles, organics, bacteria, and pathogens. Reverse osmosis is a method that removes a wide variety of salts from water to produce high purity.

- The Feed water analysis has been balanced to achieve a TDS of 35,000ppm.
- The following parameters that have a considerable effect on the pre-treatment and the RO are not provided in the analysis report, we have assumed the following values for design:
    - pH : 7.4
    - Iron : < 0.01 ppm
    - Reactive Silica : < 25 ppm
    - Colloidal Silica : < 3 ppm
    - Suspended Solids: < 5 ppm
    - Turbidity : < 1 NTU
    - BOD : < 5 ppm
    - COD : < 10 ppm
    - Boron : < 4 ppm
    - Chloride : 21000 ppm
    - Sodium : 12,500 ppm
    - Heavy Metals : Nil

1.6 Water Treatment Process

The ARO system follows a multi-stage water treatment process to ensure the highest level of purification. The process includes:





1.6.1 Water Collection and Transfer

Raw Water Source and Intake System

The primary water source for the treatment plant is the Naf River, from which raw water is extracted and stored in two ponds with capacities of 600 m^3 and 700 m^3.

Step 1: Raw Water Pumping

- A 5.5 HP submersible pump is used to transfer water from the river to the final reserved pond located near the RO (Reverse Osmosis) plant.

- The pumping system operates at a controlled rate to prevent excessive sediment intake.

Step 2: Water Conveyance System

- A 400-meter underground pipeline (250mm D-class) is installed at a minimum depth of 1 meter to protect against external damage and environmental factors.
- The system ensures efficient water flow and minimizes leakage.

Step 3: Power Supply for Pumping System

- A 400-meter-long electrical cable line (D11 Aluminum, 10 RM) is installed to power the drainage pump.
- Power is supplied using bamboo posts, providing an economical and sustainable alternative in remote locations.

1.6.2 Pre-Treatment Process

2.1. Raw Water Chemical Treatment

Raw water collected from the ponds undergoes chemical pre-treatment to reduce impurities, organic matter, and turbidity.

Step 1: Coagulation with Poly Aluminum Chloride (PAC)

- **Purpose:** PAC is used to coagulate suspended particles, making them settle faster.
- **Dosage:** 0.026 g/L of PAC is added to the raw water.
- **Mixing:** The chemical is dispersed evenly using an air blower, ensuring proper reaction with contaminants.

Step 2: pH Adjustment with Calcium Hydroxide

- **Purpose:** Adjusts the water's pH level to between 6.5 and 8.5 for optimal filtration.
- **Dosage:** 0.033 g/L of calcium hydroxide is added.
- **Mixing:** The air blower operates for an additional 10 minutes to ensure full chemical integration.

Step 3: Settling Period

- The chemically treated water is left undisturbed for 12 hours to allow flocculated particles to settle at the bottom of the pond.

2.2. Raw Water Reservoir Storage

- The pre-treated water is transferred to two raw water reservoir tanks (10m³ each, total 20m³) before ultrafiltration.
- This storage allows further settling and ensures a continuous supply to the next treatment stage.

1.6.3 Filtration and Purification

3.1. Ultrafiltration (UF) Treatment

After initial pre-treatment, water undergoes ultrafiltration, a process that removes bacteria, viruses, and fine suspended particles.

Step 1: Pre-Filtration

- A preliminary sand and carbon filter removes larger particles, reducing the load on UF membranes.

Step 2: Ultrafiltration Membrane Process

- Capacity: Two UF units operate at a rate of 1.5–1.8 m³ per hour each.

- Membrane Type: UF membranes have a pore size of 0.1 to 0.001 microns, effectively removing bacteria and viruses.
- Process: Water is forced through the membranes under controlled pressure, leaving contaminants behind.

Step 3: Post-Filtration Storage

- UF-treated water is stored in two 10m³ tanks (total 20m³) before moving to the next stage.

3.2. Multi-Media Filtration System

The multi-media filter further improves water quality by removing fine sediments, organic matter, and heavy metals.

Step 1: Filtration Through Different Media Layers

- Green Sand removes iron and manganese.
- Manganese Media enhances oxidation and further iron removal.
- Activated Carbon eliminates chlorine, bad odor, and organic compounds.

Step 2: Periodic Backwashing

- To maintain efficiency, backwashing is conducted at regular intervals, reversing the water flow to flush out trapped contaminants.

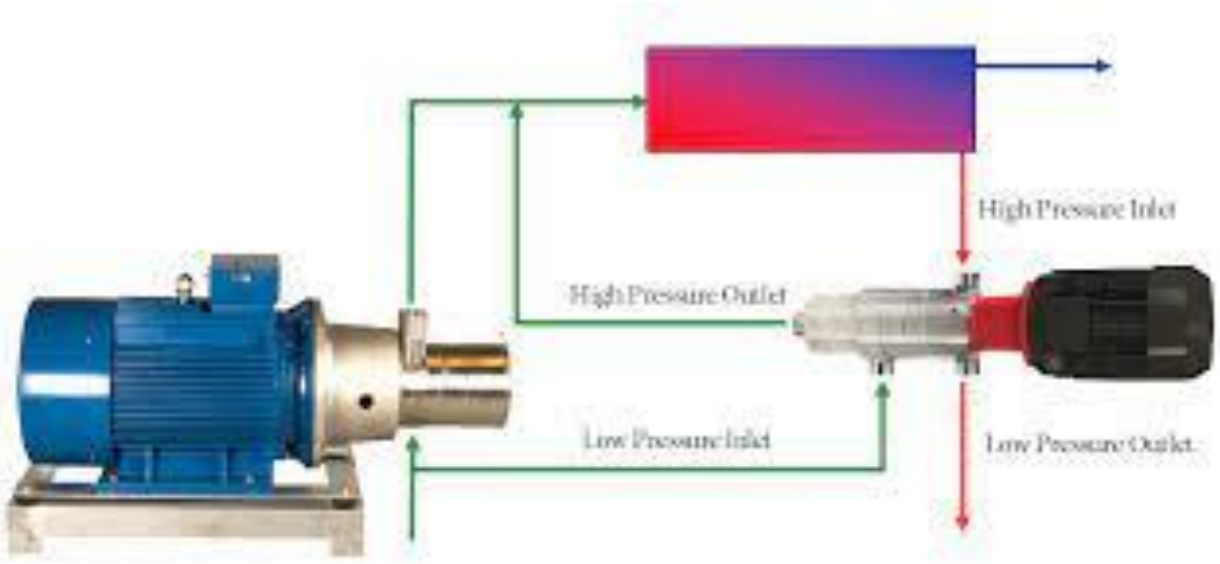
1.6.4 Reverse Osmosis (RO) Treatment

4.1. RO Filtration Process

The RO system removes dissolved salts, heavy metals, and bacteria using high-pressure membranes.

Step 1: High-Pressure Pumping

- Two Danfoss high-pressure pumps (up to 1000 PSI) ensure adequate pressure for water to pass through the RO membranes.



Step 2: RO Membrane Filtration

- **Membrane Type:** Thin-film composite Polyamide membrane (8040 model).
- **Contaminants Removed:** TDS (Total Dissolved Solids), heavy metals, and bacteria.

4.2. Pre-Treatment in RO System

- **PP (Polypropylene) Filter:** Removes residual particles before entering the RO unit.

Antiscalant Chemical Treatment:

- Prevents mineral scaling on membranes (e.g., calcium sulfate, silica).

Dosage Calculation:

- Antiscalant Quantity = (Feed Pump Flow × Antiscalant PPM × Total Running Hours) ÷ 1000
- Example: (20 × 3 × 13.5) ÷ 1000 = 0.81 liters per day.
- Antiscalant Dosage per Liter of Water = 0.02 ml

4.3. Monitoring & Quality Control

- Pressure Switches prevent overloading of high-pressure pumps.
- Rotameter measures flow rates of product and reject water.
- Conductivity Meter ensures the final water meets safety standards.

5. Final Storage and Distribution

5.1. Treated Water Storage

- The purified RO-treated water is stored in dedicated reservoir tanks before distribution.

5.2. Water Distribution System

- A 25 HP centrifugal booster pump supplies treated water over 3,500 meters.
- Topographical Challenges: Due to lowland terrain, a high-capacity pump is necessary to maintain consistent water pressure.

6. Final Quality Check

The treated water undergoes final testing to ensure compliance with drinking water standards. This comprehensive treatment process ensures that the water is free from contaminants and safe for human consumption.

1.7 Electricity Supply

The plant operates with a 440-volt electric supply sourced from the Palli Bidyut line. It features an on-site 150 KVA step-down transformer with an input voltage of 11 KV and an output of 0.44 KV. The system includes LT switchgear (300 KVA) and a 90 KVA power factor improvement unit. To maintain voltage stability, a 250-amp, 440-volt automatic phase failure switchgear is installed, which automatically disconnects the power supply if the voltage drops below the required level.

Alternative Electricity Supply:

A 150 KW diesel generator is installed as an alternative power source to ensure uninterrupted electricity supply for water production, addressing frequent load shedding and voltage fluctuations.

Specification of Generator:

- **Engine**: Six-cylinder configuration for smooth and reliable operation.
- **Power Output:** 150 kW, suitable for heavy-duty applications.

- **Voltage Range**: Supports 440V to 230V, accommodating various operational requirements.
- **Fuel Efficiency:** Presently consumes approximately 17-18 liters per hour.

Maintenance of Generator:

To proper maintenance of the Generator below measures should be followed.

- **Engine Oil and Mobil Filter:** Change every 200 operating hours.
- **Diesel Filter:** Replace every 150 operating hours.
- **Coolant:** Replace every 600 operating hours.
- **General Servicing:** Perform comprehensive maintenance every 3,000 operating hours.

1.8 Water Quality Monitoring & Control Measures

No.	Process	Description	Monitoring & Control Measures	Responsible Person	Frequency
1	Initial Water Collection	If water contains high turbidity, it should not be used without proper filtration.	Monitor turbidity and ensure proper filtration.	Water Treatment Operator	Daily
2	Water Storage	Properly store the water to prevent contamination.	Conduct regular inspections of storage tanks.	Water Treatment Operator	Weekly
3	Water Testing	Before use, test water quality parameters.	Ensure water meets quality standards before use.	Water Treatment Operator	Monthly
4	Filtration	Filtration should be performed correctly to remove impurities.	Conduct maintenance and backwashing regularly.	Water Treatment Operator	Weekly
5	Chemical Treatment	Apply appropriate chemical treatment if necessary.	Ensure correct chemical dosage is used.	Water Treatment Operator	As required
6	Reverse Osmosis (RO) Filtration	Ensure RO filters are functioning properly.	Regularly inspect and replace filters.	Water Treatment Operator	Monthly
7	UV Sterilization	Ensure UV system is operational.	Conduct UV intensity tests periodically.	Water Treatment Operator	Monthly
8	Activated Carbon Filtration	Ensure proper functioning of carbon filters.	Replace carbon filters when needed.	Water Treatment Operator	Quarterly

9	Softening Treatment	If required, use a water softener.	Monitor and adjust softening levels.	Water Treatment Operator	As needed
10	Residual Disinfection	Maintain residual disinfectant levels.	Check disinfectant concentration regularly.	Water Treatment Operator	Daily
11	Final Water Testing	Before distribution, ensure water meets safety standards.	Conduct final quality checks.	Water Treatment Operator	Weekly
12	Storage & Distribution	Store treated water safely to prevent recontamination.	Inspect storage tanks and pipelines.	Water Treatment Operator	Weekly
13	Routine Maintenance	Conduct periodic maintenance of treatment system.	Perform maintenance tasks as per schedule.	Water Treatment Operator	Monthly
14	Emergency Response	Take corrective actions in case of system failure.	Implement emergency response plan.	Water Treatment Operator	As needed
15	Documentation & Reporting	Maintain records of treatment activities.	Keep detailed logs of operations.	Water Treatment Operator	Ongoing
16	Monitoring Equipment Calibration	Ensure all monitoring equipment is properly calibrated.	Conduct calibration as per manufacturer's guidelines.	Water Treatment Operator	Annually

ARO ensures that the treated water is safe and meets all health and environmental safety standards. By following these monitoring and safety measures, communities can be provided with clean and safe drinking water, minimizing the risk of waterborne diseases.

1.9 Daily Checks and records for RO Plant:

Maintaining a Reverse Osmosis (RO) plant requires consistent monitoring to prevent membrane scaling, fouling, and equipment failure. Keeping an accurate log sheet is the best way to spot trends before they become expensive repairs.

Here are the essential daily checks and parameters you should record.

- **Operational Pressure Checks for pump:**

Pressure differentials are the "vitals" of an RO system. They tell you exactly when the filters are clogging, or the membranes are struggling.

- **Feed Pressure:** The pressure of the water entering the system.

- **Pre-Filter Pressure Drop (ΔP):** Measure the pressure before and after the sediment/cartridge filters.
- **Membrane High Pressure:** The pressure applied to the RO membranes.
- **Concentrate (Reject) Pressure:** The pressure of the wastewater leaving the vessel.

- **Flow Rate Monitoring**

Changes in flow usually indicate membrane fouling or pump issues.

- **Permeate Flow:** How much product water you are making (usually in GPM or m3/h).
- **Concentrate Flow:** How much water is being sent to the drain.
- **Electricity consuming rate:** Electricity consuming rate for pick hour and off pick hour, record this rate.
- **Recovery Rate (%):** Calculate this daily to ensure the system is operating within design specs:

Recovery %= (Feed Flow/Permeate Flow) ×100

- **Water Quality Parameters**

Water quality parameter must check in daily basis for raw water and treated water and keep record as per daily register book or in kobo software.

- **TDS (Total Dissolved Solids):** Measure both raw water TDS and treated water TDS and keep record.
- **Salinity:** Measure both raw water salinity and treated water salinity and keep record.
- **pH Levels:** Crucial for preventing scale. Check the raw water & treated water pH value and keep record.
- **Temperature:** RO membranes are sensitive to temperature. As water gets colder, permeate flow decreases.
- **Chlorine (HTH):** Measure daily free residual chlorine test at tap stand and household level before distribution and maintain FRC result as per standard 0.2-0.5.
- **Mechanical & Visual Inspection**
- **Pump Vibration/Noise:** Listen for cavitation or unusual bearing noise in the high-pressure pump.
- **Leaks:** Check all fittings, especially around the membrane housing endcaps.
- **Control Panel:** Verify there are no active alarms or warning lights.
- **Operational Record**
- **Time sheet:** Keep the record on daily basis water production and distribution timesheet.
- **Log sheet for fuel:** Keep the record and maintain on daily basis generation fuel log sheeting

1.10 Technical Staff & Volunteer

This team is on the front lines, ensuring the physical process of desalination and filtration happens correctly.

- **RO Plant Technician cum Operator**

- **Operate RO Machine:** Daily 8 hours basic 03 person operate Ro machine for ensuring water production and supply.
- Recording pressure gauges, flow rates (permeate and concentrate), and conductivity levels in the daily logbook.
- **Chemical Dosing:** Preparing and monitoring antiscalant, chlorine, or pH adjustment tanks to ensure correct dosing levels.
- **System Backwashing:** Performing manual or automated backwashing of sand and carbon filters.
- **Cleaning in Place (CIP):** Executing the chemical cleaning of membranes when the differential pressure increases.
- **First Response:** Shutting down the system immediately in case of leakages, unusual noise, or high-pressure alarms.
- **Preventive Maintenance:** Greasing pumps, checking valve seals, and inspecting high-pressure pump couplings.
- **Electrical Safety:** Inspecting VFDs (Variable Frequency Drives), control panels, and ensuring sensors (level/pressure) are calibrated.
- **Membrane Replacement:** Managing the physical extraction and installation of RO membranes.
- **Sampling:** Collecting water samples from raw, filtered, and product water stages.
- **Testing:** Measuring TDS (Total Dissolved Solids), pH, Hardness, SDI (Silt Density Index), and Chlorine residuals.
- **Compliance:** Ensuring the final product meets local (e.g., WHO or WASH Sector) drinking water standards.

- **Project Engineer**

This team ensures the plant meets its production targets while staying within budget.

- **Production & Distribution Planning:** Scheduling run-times to meet water demand while optimizing energy use and supply to the field level.
- **Prepared Budget:** Prepared yearly budget for the plant
- **Materials Purchasing:** All the materials pump and equipment purchase processing with Logistics Officer
- **Regular Basis Follow up:** Regular basis machineries, pump, generator performance follow-up.

- **Water Quality check:** Water quality check for raw water and treated water and take initiative on it.
- **Standard Operating Procedures (SOPs):** Developing and enforcing safety protocols and operational manuals.
- **Reporting:** Consolidating technical logs into weekly/monthly performance reports for upper management.
- **Staff Training:** Ensuring all operators are trained on emergency shutdown procedures and chemical handling.

- **WATSAN Manager**

This team ensures the plant meets its production targets while staying within budget.

- **Planning:** Yearly planning for RO Plant
- **Implementing:** Implementing the Whole RO plant Project.
- **Prepared Budget:** Managing and approval of yearly budget for the plant.
- **Coordination:** Coordination with doner, govt. and other stakeholder.
- **Reporting:** Consolidating technical logs into weekly/monthly performance reports for upper management.
- **Staff Training:** Ensuring all operators are trained on emergency shutdown procedures and chemical handling.

- **Logistics & Supply Chain Officer**
- **Inventory Management:** Tracking levels of consumables like cartridges, membranes, and chemicals (Antiscalant, SMBS).
- **Procurement:** Sourcing high-quality spare parts and negotiating with vendors for timely delivery.
- **Storage:** Ensuring chemicals are stored in a climate-controlled, ventilated environment according to Safety Data Sheets (SDS).
- **Finance & Accounting Officer**
- **Cost Analysis:** Monitoring the "Cost per Cubic Meter" of water produced (Energy + Chemicals + Labor).
- **Budgeting:** Allocating funds for major capital expenditures (CAPEX), such as membrane overhauls or pump replacements.
- **Utility Billing:** Managing payments for raw water intake and high-voltage electricity consumption.

- **Water Distribution Volunteer**

- Daily receive treated water from the ARO TCO and confirm it to him.
- After receiving and fill-up the tank chlorinated all the water properly as per PE direction in daily basis and distribute water. ARO TCO follow-up it on regular basis.
- Before water distribution clean the tap stand platform properly. Ensure proper serial of beneficiaries and their container cleaning status.

- Volunteer will clean the reservoir tank on monthly basis as per PE direction and follow up water pipeline regularly.
- Daily maintain water production and distribution register book and report to ARO TCO.
- Assist Plumber and Water Quality test volunteer for repair & maintenance and water quality test.
- The Water distribution volunteer will communicate with the respective teams – ARO TCO after completing the distribution work. Once the Water Facility repair is completed PE will acknowledge its completion.
- According to the schedule, perform FRC monitoring and testing from the tap stands in the water supply network. Project Engineers will oversee the FRC-level monitoring.

- **Security Guard**

- Duty time 8-hour shift per day. Properly in out signature and handover materials properly for next shift guard.
- Keep following the boundary and cleaning the DEWATS & HUB Office properly.
- Look over on regular basis all the materials and equipment.
- Maintain gate in and out pass register also visitor book and gate entry register.
- Secured all the materials and equipment inside the DEWATS & HUB Office compound.
- Frequent observation of the storeroom, office room & machine room.
- Restricted people to enter and stay near the warehouse.
- Promptly communicate with the line manager if any occurrence happens.
- Inform camp legal authority promptly if any occurrence happens.

1.11 Common Operational Difficulties in RO Plant:

Reverse Osmosis (RO) plants can face several operational difficulties, affecting performance, water quality, and system longevity. Here are common challenges:

- **Membrane Fouling**
- **Types:** Biological, scaling (e.g., $CaCO_3$), organic, colloidal, or chemical fouling.
- **Causes:** Poor pretreatment, high feedwater turbidity, inadequate cleaning cycles.
- **Effects:** Reduced permeate flow, increased pressure drop, shorter membrane life.
- **Scaling**
- **Common Scalants:** Calcium carbonate, calcium sulfate, barium sulfate, silica.
- **Solution:** Use of antiscalants, pH adjustment, and proper pretreatment.
- **Membrane Damage**
- **Causes:** High pressure surges, incorrect pH, oxidant exposure (e.g., chlorine).
- **Effect:** Permanent loss in salt rejection, physical tears or compaction.
- **High Energy Consumption**

- RO systems are pressure-driven and can be energy-intensive.
- **Solution:** Use energy recovery devices and optimize pump efficiency.
- **Pretreatment Failures**
- **Issues:** Poor filtration, chlorination issues, inadequate antiscalant dosing.
- **Impact:** Leads to membrane fouling or damage.
- **Microbiological Growth (Biofouling)**
- Occurs especially in warm climates or when disinfection fails.
- **Signs:** Rapid pressure increase, slimy deposits, poor permeate quality.
- **Control:** Regular chemical cleaning, biocide use, and sanitation.
- **Pressure Drops or Inconsistencies**
- **Causes:** Fouling, air locks, valve issues, or pump failures.
- **Monitoring:** Use differential pressure gauges and flow meters.
- **System Leaks or Mechanical Failures**
- **Components Affected:** O-rings, housings, valves, and connectors.
- **Preventive Action:** Regular inspection and maintenance.
- **Inadequate Cleaning-In-Place (CIP) Procedures**
- **Problem:** Improper or infrequent cleaning reduces membrane life.
- **Fix:** Follow manufacturer-recommended CIP protocols regularly.

Precautionary Measures for RO Plant Operation:

- **Proper Pre-treatment**
- Install multimedia filters, activated carbon filters, and cartridge filters.
- Maintain SDI < 5 for feed water to protect membranes.
- **Regular Cleaning (CIP - Clean-in-Place)**
- Schedule chemical cleaning based on pressure drop and performance decline.
- Use appropriate cleaning chemicals (acidic/alkaline) based on foulant type.
- **Monitor Operating Parameters**
- Track pressure, flow rate, conductivity, and recovery rates.
- Implement alarms for deviations.
- **Antiscalant and Biocide Dosing**
- Use antiscalant to prevent scaling.
- Dose biocide periodically to control biological growth (ensure membrane compatibility).
- **Avoid Chlorine Damage**
- Ensure free chlorine is removed from feed water (using carbon filters or sodium bisulfite).
- **Maintain pH and Temperature**

- Feed water pH: Typically, between 6.5–7.5.
- Temperature: Preferably 20–30°C for optimal membrane performance.
- **Regular Inspection and Maintenance**
- Inspect membrane elements, O-rings, seals, and piping.
- Replace filters and membranes as per schedule or performance data.
- **Operator Training**
- Ensure trained personnel operate and troubleshoot the RO plant.
- Keep documentation of SOPs (Standard Operating Procedures).

1.12 Maintenance Guidelines

- **Pre-Treatment System Maintenance**
- Pond Cleaning: Remove sediment and organic matter every two months.
- Polythene Cover Inspection: Check for wear and tear to prevent leaks.
- Monitor algae growth and take necessary preventive actions.

- **Ultrafiltration System Maintenance**
- Membrane Cleaning: Regular cleaning to prevent clogging.
- Pre-Filter Replacement : Ensuring consistent filtration efficience.
- Inspect seals and gaskets to prevent leaks.

- **Multi-Media Filter Maintenance**
- Backwashing Schedule: Routine backwashing to maintain filter efficiency.
- Check media condition and replace when necessary.

- **RO System Maintenance**
- Pump Operation Checks: Avoid dry running to prevent damage.
- Voltage Monitoring: Maintain power supply between 350–440V.
- Membrane Cleaning & Replacement: Regular servicing to prevent fouling.
- Monitor and log water rejection rates for system efficiency.

- **Storage and Distribution Maintenance**
- Reservoir Cleaning: Monthly cleaning of tanks.
- Leak Inspections: Regular pipeline and valve checks.
- Ensure pipelines are free from biofilm buildup.

- **Safety Measures for Water Treatment Operations**
- Workers must wear protective equipment while handling chemicals.

- Hazardous chemicals should be securely stored.
- Emergency response plans should be in place and regularly tested.
- Safety inspections should be conducted to mitigate potential hazards.
- Implement a risk assessment plan for identifying operational hazards.
- Conduct periodic safety drills to ensure staff preparedness.

- **Performance Audits & Continuous Improvement**
- Conduct periodic audits to assess system efficiency and compliance.
- Collect feedback from operators and stakeholders for improvements.
- Update procedures based on new technological advancements and best practices.

1.13 Conclusion

Proper implementation and maintenance of the Advance Reverse Osmosis (ARO) Water Treatment System require coordinated efforts from relevant stakeholders. Regular monitoring and safety measures are essential to ensure clean and safe water for all users. The guidelines outlined here should be strictly followed to maintain the system's efficiency and sustainability.

1.14 Water Quality Test Report

RRRC

DSK ARO SEA WATER DESALINATION PLANT

Gender-Sensitive Humanitarian Assistance in WASH for the Rohingya Refugee and Host Communities in Teknaf, Cox's Bazar.

Project Code: BGD 1060

Water Quality Test Report

Raw Water (Naf River) Test Report

Bureau of Research, Testing and Consultation (BRTC)
Department of Civil Engineering
Chittagong University of Engineering & Technology (CUET)
Chattogram-4349, Bangladesh

TEST REPORT

Memo No. : BRTC/TEST/CE/2025/1491 Date: 19/03/2025
Supplier : WATSAN Manager, DSK, DSK WHH WASH Project, Camp-24, Cox's Bazar
Ref. No : Letter Date: 19/03/2025
Name of the Test : **Water Quality Test**
Location : Untreated Water (Naf River), DSK ARO Plant
Sample : **Unsealed**

Test Results for Water Quality Parameters

Parameters	Unit	Concentration present	Bangladesh Standards for Drinking Water (*ECR, 2023)
pH	---	6.9	6.5 - 8.5
Colour	Hazen Unit	20.0	15
Chloride	mg/L	8950.0	250 (1000 for Coastal Areas)
TDS	mg/L	21150.0	1000
Turbidity	NTU	13.5	5
Hardness	mg/L (as $CaCO_3$)	6200.0	500
Iron	mg/L	0.2	0.3 - 1.0
Manganese	mg/L	0.986	0.4
Total Coliform	CFU/100mL	0.0	0
Fecal Coliform	CFU/100mL	0.0	0
Arsenic	mg/L	0.0	0.05
Salinity	mg/L	16169.5	No Standard

* The Environment Conservation Rules

Remarks:
- The samples supplied by the client have been tested in the laboratory

Countersigned by
24.03.25
Head
Department of Civil Engineering, CUET

Test Conducted by
24/03/25
Mohammad Saiful Islam
Assistant Professor

Raw Water/ Untreated water at Naf River test report:
http://www.civilcuet.com/h.php?p=F2FhPA94

ARO Treated Water Test Report

Bureau of Research, Testing and Consultation (BRTC)
Department of Civil Engineering
Chittagong University of Engineering & Technology (CUET)
Chattogram-4349, Bangladesh

TEST REPORT

Memo No. : BRTC/TEST/CE/2025/1492 Date: 19/03/2025
Supplier : WATSAN Manager, DSK, DSK WHH WASH Project, Camp-24, Cox's Bazar
Ref. No : Letter Date: 19/03/2025
Name of the Test : **Water Quality Test**
Location : Treated Water (Naf River), DSK ARO Plant
Sample : **Unsealed**

Test Results for Water Quality Parameters

Parameters	Unit	Concentration present	Bangladesh Standards for Drinking Water (*ECR, 2023)
pH	---	7.4	6.5 - 8.5
Colour	Hazen Unit	5.0	15
Chloride	mg/L	430.0	250 (1000 for Coastal Areas)
TDS	mg/L	880.0	1000
Turbidity	NTU	1.5	5
Hardness	mg/L (as $CaCO_3$)	100.0	500
Iron	mg/L	0.2	0.3 - 1.0
Manganese	mg/L	0.005	0.4
Total Coliform	CFU/100mL	0.0	0
Fecal Coliform	CFU/100mL	0.0	0
Arsenic	mg/L	0.0	0.05
Salinity	mg/L	776.9	No Standard

* The Environment Conservation Rules

Remarks:
- The samples supplied by the client have been tested in the laboratory

Countersigned by
24.03.25
Head
Department of Civil Engineering, CUET

Test Conducted by
24/03/25
Mohammad Saiful Islam
Assistant Professor

ARO treated water test report:
http://www.civilcuet.com/h.php?p=g0ahEc43