EMPLOYER'S REQUIREMENTS FOR CONSTRUCTION OF NEW RO PLANT AND BOREHOLE

VANDHOO REGIONAL WASTE MANAGEMENT FACILITY
MINISTRY OF ENVIRONMENT

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1.1. Scope

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ii. **Reverse Osmosis Plant:** Supply / Construction & Installation of Reverse Osmosis plant, seawater intake boreholes and associated works, permeate & brine reject lines, based on detail given on drawings, BOQ & Technical Specification.

iii. **Chlorine Dosing System:** Installation of Chlorine Dosing System based on detail given on Drawings, BOQ & Technical Specification.

1.2. Summary of Standards

A summary of standards referred to in various Sections of the Technical Specifications. The Clause reference is given together with the Clause title used in the Section.

Section 2- Borehole Design	
Borehole drilling Technical specification & Guidelines	Borehole drilling Technical specification & Guidelines - Environmental Protection Agency, Maldives
DIN 8061	Unplasticized polyvinyl chloride (PVC-U) pipes –. General quality requirements and testing.
DIN 8062	Unplasticized polyvinyl chloride (PVC-U) pipes –. Dimensions
ISO 161-1:1996	Thermoplastics pipes for the conveyance of fluids -- Nominal outside diameters and nominal pressures -- Part 1: Metric series
Section 3 – Reverse Osmosis Plant	
Desalination Plant Regulation	Environmental Protection Agency, Male Maldives

BS EN 14652:2005 +A1:2007	Water conditioning equipment inside buildings. Membrane separation devices. Requirements for performance, safety and testing
BS EN 14812:2005+A1:2007	Water conditioning equipment inside buildings. Chemical dosing systems. Pre-set dosing systems. Requirements for performance, safety and testing
BS EN 15848:2010	Water conditioning equipment inside buildings. Adjustable chemical dosing systems. Requirements for performance, safety and testing
NSF/ANSI 58-2009	Reverse Osmosis Drinking Water Treatment Systems
AWWA M46	American Water Works Association Standard for Reverse Osmosis and Nanofiltration

SECTION 2 - BOREHOLE

2.1. Scope

This section specifies the requirements for the boreholes drilled for the intake of seawater for the Reverse Osmosis plant. The drilling process, well casing, sealing and pump testing of the boreholes are included in this section.

2.2. Definitions

The definitions given in the relevant standards, which are referred to in the specification, shall apply for the terms used in this specification.

2.3. Reference Standards

The following standards are referred to in this section and the drawings relevant to this section;

Borehole drilling Technical specification & Guidelines	Borehole drilling Technical specification & Guidelines - Environmental Protection Agency, Maldives

DIN 8061	Unplasticized polyvinyl chloride (PVC-U) pipes –. General quality requirements and testing.
DIN 8062	Unplasticized polyvinyl chloride (PVC-U) pipes –. Dimensions
ISO 161-1:1996	Thermoplastics pipes for the conveyance of fluids -- Nominal outside diameters and nominal pressures -- Part 1: Metric series

2.4. Borehole Design

2.4.1. Borehole Drilling

Borehole drilling procedures must follow the guideline released by EPA "Borehole drilling Technical specification & Guidelines". The contractor shall employ his reverse circulation to drill the holes of size and depths indicated in the design. The contractor shall provide all equipment required for the borehole drilling process.

The contractor shall make his own arrangement for water required for drilling purposes and also for ancillary excavation. He shall also arrange for the drilling mud and mud pump etc., where required. Any precautions or steps required to control caving of the bore hole shall also be the responsibility of the contractor.

The Contractor must consider safety requirements including first aid. All care and precautions should be taken and it should be ensured that there shall be no accidents while drilling the borehole. Proper dress and equipment like gumboots, helmets and tents for drilling shall be provided to the workmen at site.

2.4.2. Preparation of the Borehole Site

The Contractor must prevent foreign materials and surface water from entering drilled hole by exercising precaution.

The Contractor shall protect the adjacent terrain and surface water from siltation and contamination. Construct a settling basin to contain the drilling fluid, cuttings and compounds and provide a means to filter sediment prior to discharging excess water.

2.4.3. Diameter of the Borehole

The diameter of the boreholes shall be as below unless mentioned in the drawings

Size in Inches(mm)
8.625 (219.1mm)

2.4.4. Depth of borehole

The in-land borehole depth shall not be less than 30 m. As per the borehole drilling guidelines published by EPA, continue drilling up to 30m and check whether the electrical conductivity of discharge water has reached 50-60mS/cm. If electrical conductivity of discharge water at 30 m depth is measured less than 50-60mS/cm, continue drilling until electrical conductivity reaches to 50-60mS/cm.

2.5. Drilling Method

The Contractor shall use a rotary drilling technique that is capable of achieving the required depth and diameter. The use of bentonite mud and other drilling fluid additives must be of a low solid and non-toxic nature and approved by the Engineer.

2.6. Water Sampling and Quality Testing

Water samples must be taken by the Contractor for the purposes of testing the physical, chemical and bacteriological quality during the pumping tests. Water samples must be collected in sterilized, and properly marked plastic bottles each of one liter capacity.

2.7. Water Sample Parameters

The Contractor shall be responsible for testing the following parameters of the collected water samples.

- Turbidity
- Colour
- pH
- Concentrations of Ca, Mg, Na, HCO_3, SO_4, NH_3, Cl, Mn, Fe, F, Hg, Cd, K in mg/l
- Total dissolved solids TDS (mg/l)
- Electrical Conductivity EC (µS/cm)
- Calcium and Magnesium Hardness (mg/l)
- M-Alkalinity,
- Bacteriological tests.

The aforementioned chemical tests must be completed within 24 hours after sample collection in the containers specified by testing authority.

2.8. Sample Collection and Borehole feasibility test

Borehole Feasibility tests must be carried out by the Contractor. The contractor should take samples of stratum at his cost at every 3 m or often where the Stratum changes and shall preserve these samples for the inspection of the Engineer.

In addition to this water samples for analysis should be collected in 2 Liter bottles made of glass, polyethylene or hard rubber. Through washing and rinsing must be carried out before the water sample collection

2.9. Casing and Screens

Well casing and screens shall be provided by the Contractor to prevent well caving in, preventing surface water/shallow groundwater from entering the well and protecting the pump and other equipment from damage. Steel casing used in water wells should conform to the standards of the American Society for Testing and Materials (ASTM), British Standards Institute (BSI) or American Petroleum Institute (API). Plastic casing may be of several types: Polyvinyl chloride (PVC), Acrylonitrile butadiene styrene (ABS), rubber-modified polystyrene (SR), High Density PolyEthylene (HDPE), polyolefin, polypropylene, and Glass-reinforced plastic (GRP or ‘glass fibre’). Plastic casing must have sufficient strength to withstand the pressure and setting temperature of the cement grout that will be placed in the annulus outside the casing.

2.9.1. Temporary Surface Casing

The Contractor shall furnish, install, and remove all temporary surfaces casing necessary to support the walls of the larger well bore where the grout surface seal is to be placed.

2.9.2. Length of Permanent Casing

The minimum length of the permanent well casing shall be determined by the Contractor as mentioned in Clause 2.4.4. The use of centering guides can ensure that the permanent well

casing remains centred in the drill hole. The permanent casing should comply with DIN 8061 and DIN 8062 or (ISO 161/1) standards.

2.10. Grout Seal (Sanitary Seal)

To provide an effective seal against the entry of contaminants the grout surface seal must be constructed by the Contractor under the inspection of the Engineer. The annulus or void around the casing shall be completely backfilled by injecting pure cement grout from the bottom.

2.11. Gravel Pack

Gravel packs that are suitable for the borehole shall be provided by the Contractor. The artificial filter pack (gravel pack) is usually placed around a well screen drawing water from an aquifer comprising sand to fine gravel grain sizes. The pack is placed around the screen to help support the well walls and keep out fine sediment.

2.12. Reporting and Supervision

Under the supervision of a hydrogeologist, the results of drilling and testing shall be documented and submitted by the Contractor in the form of a report, which includes the following.

- Daily job record
- Drilling record, geological time log and casing program etc
- Pumping test report
- Water analysis report
- Water observation data
- Data analysis for aquifer parameters i.e. safe yield, co-efficient of permeability, Horizontal Conductivity etc.
- Daily Record
- Site name
- Reference number of borehole
- GPS Co-ordinates of borehole (latitude / longitude)
- Date of reporting
- Names of foreman and drillers
- Method of drilling

- Make, model, type and size of drilling rig
- Diameter of hole, and depth of changes in diameter
- Depth of hole at start and end of shift or working day
- Depth and size of casing at start and end of shift or working day
- Description of strata drilled with depth of transitions encountered
- Depth at which water is struck
- Yield of air lifted water, when drilling or developing with air in litres per second.
- Time log showing rate of penetration in minutes per metre, type of bit, standby time due to breakdown.
- Depth intervals at which formation samples are taken
- Records of components and quantities used or added to the drilling fluid or air.
- Water level at the start of each working day
- Electrical conductivity measurements during test pumping
- Problems encountered during drilling
- Details of installations in the borehole (if any)
- Depth, size and description of well casing
- Depth, size and description of well screens
- Aquifer depth and SWL after completion of well

2.13. Pumping Test

The Contractor shall supply all pumps and equipment required to carry out the discharge pumping test under the supervision of the Engineer. During the pumping test, the drawdown in feet below static level and the pumping rate shall be measured at least every 2 minutes until drawdown stabilizes and every 10 minutes thereafter.

2.13.1. Testing Procedure

Test pump at appropriate pressure and continue pumping for another 4 hours if the water level stabilizes at less than 50 percent of the static water depth. However, if the drawdown is greater than 50 percent of the static water depth, the pumping rate must be reduced. After completion of pumping, water level recovery must be recorded every 5 minutes until static water depth is reached.

2.13.2. Measuring Devices

The Contractor shall provide the following measuring devices:

- Electrical Conductivity meter to take electrical conductivity readings of the discharge water during test pumping
- Flow Rate measurement device to measure the flow of water.
- Flow Control devices such as gate valves on pump discharges to control the water flow rate
- Control panel display must include a TDS meter or a conductivity meter

2.14. Borehole Development

The Contractor shall develop and clean the boreholes upon completion of the drilling and installation of casing, screens, grouting and gravel pack are installed, in order to remove native silts, clays, loose rock particles and drilling fluid residues deposited on the borehole wall during the drilling process.

2.15. Borehole Disinfection

All boreholes must be disinfected after the completion by the following methods.

2.15.1. Cleaning

Cleaning of the well through the removal of all foreign substances and the application of alkalis for oil/grease removal

2.15.2. Disinfection

After cleaning, disinfect the borehole by placing a chlorine solution into the well so that a concentration of at least 50 mg/l (0.005%) of available chlorine exists in all parts of the well at static conditions. The disinfection procedure should involve washing of the borehole walls, the testing and removal of chlorine residual as well as carrying out bacteriological tests.

SECTION 3 – REVERSE OSMOSIS PLANT

3.1. Scope

This part specifies the requirements for Reverse Osmosis Plant. The following clauses specify general requirements and standard of workmanship for the equipment and installations.

3.2. Definitions

The definitions given in the relevant standards which are referred to in the specification, shall apply for the terms used in this specification.

3.3. Reference Standards

The following standards must be referred to any components designed in this section and the drawings relevant to this section.

Desalination Plant Regulation	Environmental Protection Agency, Male Maldives
BS EN 14652:2005 +A1:2007	Water conditioning equipment inside buildings. Membrane separation devices. Requirements for performance, safety and testing
BS EN 14812:2005+A1:2007	Water conditioning equipment inside buildings. Chemical dosing systems. Pre-set dosing systems. Requirements for performance, safety and testing
BS EN 15848:2010	Water conditioning equipment inside buildings. Adjustable chemical dosing systems. Requirements for performance, safety and testing
NSF/ANSI 58-2009	Reverse Osmosis Drinking Water Treatment Systems
AWWA M46	American Water Works Association Standard for Reverse Osmosis and Nanofiltration

ASTM D4195 - 08(2014)	Standard Guide for Water Analysis for Reverse Osmosis and Nanofiltration Application

3.4. General

The RO module and components should conform to BS EN 14652 and NSF/ANSI Standard 58 which establishes the minimum requirements for the certification of point of use (POU) reverse osmosis filter systems. The standard includes materials used, structural integrity and safety, product literature, total dissolved solids (TDS) reduction and additional contaminant reduction claims.

3.5. Source Water Conditioning

The water taken through the borehole pump must be conditioned through chemical dosing systems and must conform to BS EN 14812 and BS EN 15848.Chemical dosing systems will involve storage and feed solution preparation tanks and chemical feed pumps. The chemicals must be stored on-site in buildings or storage areas that allow their safe loading, containment, and handling. The following dosing systems must be used

- Sodium metabisulfite dosing station
  Sodium metabisulfite must be used to dechlorinate the raw water intake from boreholes.
- Flocculant dosing station
  Flocculants must be applied to improve seawater pre-treatment by the formation of large flocs which can be removed through pre-treatment methods. However flocculant overdoing must be avoided as it may cause organic fouling of the RO membranes.
- Antiscalant dosing station
  Scale inhibitors must be used to prevent the formation of mineral deposits (scaling) on the surface of the RO membranes

3.6. Pretreatment (Filter System)

Membrane treatment may be achieved through membrane filtration methods or granular media filtration. The most suitable pretreatment system type and configuration mainly

depends on the source water quality, and more specifically on the type of foulants present in the source water which must be tested by the Contractor.

3.6.1. Sand Filters

The RO plant must be equipped with sand filters to minimize the content of coarse materials such as grit, debris, and suspended solids collected by the plant intake and to protect downstream filtration facilities from solids overloading. Once the filter media head losses reach a preset maximum level, the filter must be taken out of service and media backwash must be activated.

3.6.2. Filter Media

The Contractor must provide the type, uniformity, size, depth of filter media used as pre-treatment filters.

The effective size d10 of the medium is the size of the opening of the sieve for which 10 percent of the grains (by weight) are smaller in diameter.

The uniformity coefficient (UC) is the ratio between the opening size d60 of a sieve for which 60 percent of the grains (by weight) are smaller and the effective size of the medium.

$$\boldsymbol{UC = d_{60}/d_{10}}$$

The media size and uniformity coefficient should decrease along the direction of the flow, while the specific density should increase to prevent the intermixing of different filter media. As a general rule of thumb the ratio of the depth of the filter bed and effective size of the filter media should be between 1000-1500.

A layer of granular activated carbon (GAC) may also be used to provide bio-filtration by the microorganisms that grow on a thin biofilm formed on the granular carbon layer.

3.6.3. Filter Media Backwash

Granular media filters can be typically backwashed using filtered source water or concentrate from the RO membrane system. The backwash frequency of filter cells is usually once every 24 to 48 h. The applied bed expansion during backwash depends on the size of the filter media—the smaller the media, the larger expansion will be needed.

3.7. Membrane Filtration

Microfiltration (MF) or ultrafiltration (UF) may be used, as saline water pretreatment, to remove particles, colloids and organics which may cause RO membrane fouling.

3.7.1. Filtration

The Contractor must provide the membrane flux and trans membrane pressure (TMP) of the membranes as these are the most important performance factors associated with the filtration cycle of membrane pretreatment systems

3.7.2. Backwash

Backwash, that usually applies combination of filtered water and air, must be initiated by a timer or when the threshold trans membrane pressure is reached, to periodically remove solids that accumulate on the feed side of the membrane. Chemically enhanced backwash (CEB) must be initiated when organic deposits and biofilm accumulates on the membrane surface.

3.7.3. Cleaning

Membrane cleaning must be carried out every 1 to 3 months to reduce the fouling not eliminated by periodic backwash and CEB.

3.7.4. Integrity testing

All membrane pre-treatment systems must be equipped with integrity testing features that allow the detection of occasional breaks or punctures in the membrane fibers, membrane modules, piping, and connectors; and other problems that could occur during membrane production, installation, or operation.

3.8. Reverse Osmosis Module

The Contractor must provide the configuration and specification for all the components of the RO module including the certification to the standards mentioned above.

3.8.1. High Pressure pumps

High-pressure feed pumps must be used to deliver source water to the RO membranes at the pressure required for membrane separation of the fresh water from the salts, which typically is 55 to 70 bars for seawater desalination. Variable frequency drives (VFDs) may be used with the high pressure pumps to change motor speeds and maintain the optimum pump efficiency with regard to the fluctuating pressure demands of the changes in source water salinity and temperature.

If VFDs are not used, the feed flow and pressure of the high-pressure pumps must be adjustable via a pressure control valve.

3.8.2. Seawater Desalination Elements and Membrane Configuration

Seawater Reverse Osmosis SWRO membranes must be tested against the standard test feed salinity and pressure conditions of 32,000 mg/L of NaCl and 55.2 bars. The Contractor must also provide the applied membrane test recovery and test recovery rate from the membrane suppliers as well as the membrane configurations inside the pressure vessels. RO system recovery percentage should be 50% - 75%.

3.8.3. Membrane Flushing and Cleaning Systems

RO systems must be equipped with membrane flushing systems to automatically flush vessels in the RO trains on shutdown in order to remove residual concentrate and prevent RO membranes from fouling and degradation. This may be achieved by using the disinfected RO system permeates or non-chlorinated and chemically conditioned filtered water.

Accumulated foulants in the feed must be removed periodically to maintain the performance e and design life of the RO modules. A Clean-in-place (CIP) system for RO membranes can be established for this purpose

3.8.3.1. Cleaning in Place (CIP)

The capacity of the installed cleaning solution storage tank(s) must be sized such that they are sufficient to clean all vessels within the largest single RO train from a single batch of prepared solution. The CIP system must be designed to mix and recirculate a range of alternate cleaning chemicals made up with RO permeate or dechlorinated potable water. The Contractor must consult the plant membrane element supplier when making decisions regarding chemicals and cleaning procedures to be applied.

3.9. Post Treatment

3.9.1. Disinfection: Chlorine Dosing

The Contractor shall supply and install chlorine dosing unit including all accessories required to disinfect the product water to make it potable as per EPA standards.

3.9.2. Water Quality and Treatment

During the testing, commissioning and defects liability period, if the water quality and process parameters mentioned below cannot be reached, the Contractor must modify civil

structures, the mechanical, hydraulic, electrical components of the plant, operation procedures and the chemical dosing parameters in order to achieve the required performance of the plant.

pH	6.5-8.5
Temperature	25-30 ˚C
Turbidity	0.0NTU
Electrical Conductivity	<1000µS/cm
Total Dissolved Solids (TDS)	<500mg/l
Free Chlorine (if applicable)	0.2-0.5 mg/l
Chloride	<200mg/l
Boron	<0.3mg/l
Copper	<1mg/l
Fluoride	0.1-1.5mg/l
Iron	0.01-0.3mg/l
Total hardness (Ca and Mg)	<150mg/l
Iodine	0.01-0.3mg/l
Nitrates	0.0 mg/l
Nitrite	0.0 mg/l
Ammonia	0.0 mg/l
Phosphate	0.0 mg/l
Sulphate	0.0 mg/l
Sulphite	0.0 mg/l
Total Coliform (cfu/100ml)	0/100ml
Faecal Coliform (cfu/100ml)	0/100ml

The product water quality shall conform to EPA standards of supply water quality standard attached.