WATER TREATMENT AND DESALINATION PLANTS

MINISTRY OF AGRICULTURE, NATURAL RESOURCES AND ENVIRONMENT

WATER DEVELOPMENT DEPARTMENT

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- Kornos Water Treatment Plant
- Dhekelia Desalination Plant

FOREWORD

Despite the impressive development of the conventional surface water sources in the last two decades, Cyprus still faces an acute water shortage problem. The prolonged drought of the last years has drastically reduced the water reserves of the surface and underground reservoirs and has created problems in all fields of activities.

Therefore, in order to eliminate the dependency of the towns and tourist centres on annual rainfall and in view of the increasing water demand, the Government has decided to proceed with the construction of sea water desalination plants. Desalination of sea water was first introduced in April 1997, with the operation of the first desalination plant at Dhekelia, while on 4 March 1999 the Contract for a second desalination plant to be built near the Larnaca Airport was signed. Furthermore the Council of Ministers, on the 25th of August 1999, decided to construct another desalination plant, for Limassol, at Zakaki with a nominal capacity of 20 000 cubic metres per day.

At the same time the Government has turned its attention to other non-conventional sources such as the use of recycled water for irrigation, recharge and amenity purposes, the desalting of brackish water, the changing of the cropping pattern to less water demanding crops, the introduction of new effective management procedures through the establishment of a Water Entity, the efficient use of available water including the better use of pricing and water conservation measures and the preservation of the water quality.

The Government also proceeds with the development of the remaining existing water resources with the construction of dams until 2015 on Dhiarizos, Ezousas, Pedhieos, Akaki, Peristerona, Karyotis, Marathasa and Tylliria rivers. In this context, Arminou dam on Dhiarizos river was completed in 1998 and works have started for the construction of Asprokremmos Water Treatment Plant. Tamasos dam on Pedhieos river is also under construction while tenders have been invited for the construction of Kannaviou dam on Ezousas river.

The implementation of short or long term projects will not solve the water shortage problem of Cyprus, unless everybody realises that water is a scarce resource and that all of us have the responsibility and obligation to manage it correctly and to make every possible effort for its correct use and conservation.

This publication tries to present, in a simple way, the water treatment and desalination plants currently in operation in Cyprus, as well as the methods used for the production of drinking water of excellent quality.

Finally, I wish to express my thanks and sincere congratulations to the management and staff of the Water Development Department who have contributed in any way towards the preparation of this publication.

Costas Themistocleous
Minister of Agriculture,
Natural Resources and Environment

October, 1999

Water Treatment Plants and Dhekelia Desalination Plant

INTRODUCTION

Until 1970 underground water was the main source of water for both drinking and irrigation purposes. As a result almost all aquifers were seriously depleted from overpumping with the coastal aquifers suffering from sea intrusion.

The increase of population as well as the increase in the tourist and industrial activities have led to an increase in the demand for water and have created an acute shortage of potable water.

The relevant Authorities, identified the water shortage problem in time and in consultation with International Organisations, prepared a long term plan for solving the problem.

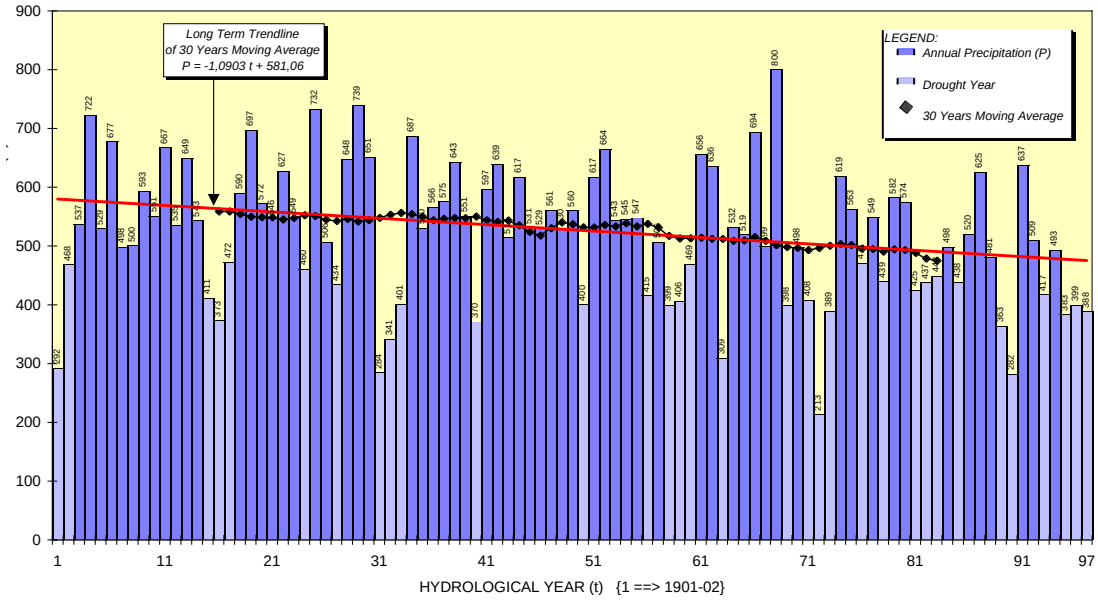
Convincing evidence of the great significance which was given and continues to be given to the rational exploitation of the water resources is the present storage capacity of the dams and ponds which has reached 303 million cubic metres of water from a mere 6 million cubic metres in 1960.

The water treatment plants of Khirokitia, Kornos, Limassol and Tersephanou were also constructed while Asprokemmos water treatment plant, which will treat and deliver water to Paphos, is expected to commence operation during the first half of 2001. Furthermore two self contained water treatment units have also been installed in 1996, for the supply of additional water to the Athienou area.

Nevertheless, despite all these developments, Cyprus still faces an acute water shortage problem. Cyprus has no rivers with perennial flow while rainfall is highly variable and droughts occur frequently. The mean annual rainfall is about 500 millimetres but records indicate that rainfall has decreased considerably and the average for the last eleven years is now estimated at 452 millimetres. More significantly, the flow of water into dams, built especially for collection and storage, has fallen by a much higher percentage. As a result, and despite many valuable resources being invested in water

Typical stream

CYPRUS ANNUAL PRECIPITATION AND 30 YEARS MOVING AVERAGE
(AREA UNDER GOVERNMENT CONTROL)



storage capacity, the quantities of water available both for drinking and irrigation purposes have not been adequate.

The scarcity of water is creating very serious problems and has acted as a constraint for the further development not only of agriculture but more significantly of other activities such as tourism and industry.

Therefore, in order to eliminate the dependency of the towns and tourist centres on annual rainfall and in view of the increasing water demand, the Government has decided to proceed with the construction of sea water desalination plants.

Desalination of sea water was first introduced in April 1997, with the operation of the first desalination plant at Dhekelia, while on 4 March 1999 the Contract for a second desalination plant to be built near the Larnaca Airport was signed. Furthermore the Council of Ministers, on the 25th of August 1999, decided to construct another desalination plant, for Limassol, at Zakaki with a nominal capacity of 20 000 cubic metres per day.

This publication tries to present, in a simple way, the water treatment and desalination plants currently in operation in Cyprus, as well as the methods used for the production of drinking water of excellent quality.

WATER TREATMENT PLANTS

GENERAL PRINCIPLES AND TREATMENT STAGES

Water treatment plants treat surface water from the dams. Raw water contains suspended and inorganic material, plant material, bacteria, protozoa, algae, gases etc. In order to remove all these foreign particles from the water and

Raw water reservoir

make the water suitable for drinking purposes the following procedures should be carried out:

- Removal of suspended matter.
- Decolourisation and oxidisation of the inorganic material and killing of all pathogenic micro-organisms by adding chlorine (prechlorination).
- Aeration of water.
- Flocculation of colloidal/organic matter with aluminium sulphate and anionic polyelectrolyte.
- Sedimentation.
- Filtering.
- Addition of lime.
- Postchlorination.

1. Removal of suspended matter

Suspended matter present in the water like leaves, water plants, soil etc. is retained at the raw water reservoir of the treatment plant.

2. Prechlorination

Chlorine has oxidising and disinfecting properties. With the addition of chlorine the various organic and inorganic materials like iron, hydrogen sulphide etc. are oxidised and all the pathogenic and other micro-organisms are killed or inactivated.

Chlorine is present at all stages of water treatment in order to ensure that there is

Chlorine storeroom

no development of pathogenic micro-organisms.

3. Aeration of Water

Air is added to the water in order to kill all anaerobic micro-organisms and to oxidise the organic material present in the water.

4. Flocculation

- ***Addition of aluminium sulphate***

The addition of aluminium sulphate is necessary in order to remove the organic particles present in the raw water and to change the colour of the water from green to clear. The aluminium sulphate attacks the colloidal particles of the water and flocs are formed. As these flocs are heavier than the water molecules, they gradually settle

Addition of chemicals

down to the bottom of the reservoir as sludge.

- ***Addition of anionic polyelectrolyte***

The addition of anionic polyelectrolyte helps the aluminium sulphate to react more quickly with the organic matter. Larger and heavier organic flocs are formed, which settle much more easily, in a period of 2 to 3 instead of 6 to 8 hours.

The addition of anionic polyelectrolyte is done in cases when the aluminium sulphate doesn't react quickly with the organic matter, especially at low temperatures in winter, in spring, when the raw water contains big quantities of algae and in the autumn when the water is very turbid, especially after very heavy rainfall.

5. Sedimentation

After the addition of aluminium sulphate and polyelectrolyte the flocs settle down, as sludge, in the sedimentation tanks. The sedimentation tanks are sometimes called clarifiers because here, the water is being clarified. The removal of sludge is done on a daily basis and the sludge is transferred to the sludge drying beds, while the water is transferred to the filters.

6. Filtering

After the sedimentation tanks, the water passes through special rapid sand filters where it is filtered in order to remove all the remaining flocs/particles which are present in the water.

The filters are washed at regular time intervals, by flashing water in the opposite direction, in order to keep them clean and

Sand filters

in good operation. The impure water is transferred to another reservoir where the sludge settles at the bottom and the water re-enters the system for retreatment.

In this way the loss of water from treatment is reduced from 3 to 4 percent to 0,5 to 1 percent.

7. Addition of lime

Lime is added to the water to correct its acidity (pH). The addition of lime is done, only when considered necessary, usually during the winter months.

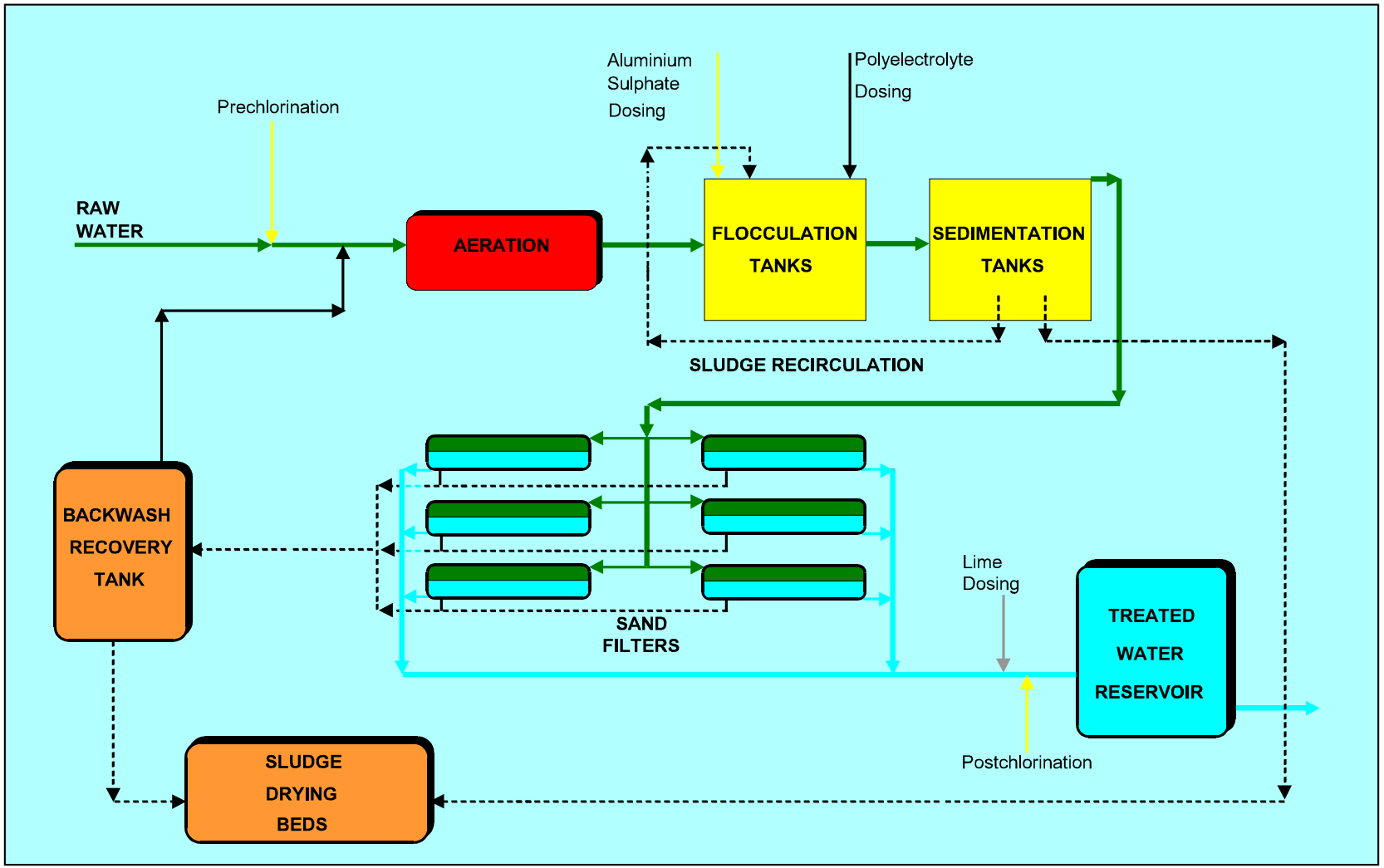
The raw water coming from the dams of Cyprus is alkaline (pH 8,0 - 8,5) but after the addition of aluminium sulphate and chlorine it becomes more acid (pH 7,0 - 7,5) and after the addition of lime the pH increases to 7,4 - 7,8.

8. Postchlrorination

After the water treatment process is completed, chlorine is again added to the water to ensure that there is no growth of any pathogenic micro-organisms in the water supplied to the Water Boards etc. The quantity of chlorine is much less than the quantity added during the prechlronination stage.

General view of flocculation and sedimentation tanks

FLOW DIAGRAM OF TREATMENT PLANT



WATER TREATMENT PLANTS
KHIROKITIA WATER TREATMENT PLANT

Khirokitia Water Treatment Plant has been in operation since 1974, with an initial nominal capacity of 22 000 cubic metres per day. In 1980 the capacity was increased to 33 000 cubic metres per day. The Plant treats raw water from the Kouris, Kalavasos and Lefkara dams and it provides drinking water to the Larnaca and Famagusta districts. With the operation of the Tersephanou Water Treatment Plant, in October 1999, the Khirokitia Plant has been put on a standby basis.

Consulting Engineers:	- Howard Humphreys & Partners Ltd	
Contractors:		
Water Development Department	- Civil Works	£ 128.270
U.F.E.L.	- Electromechanical equipment	£ 97.730
Total Cost:		**£ 226.000**

Administration building

Aerial photograph of Khirokitia Water Treatment Plant

Technical characteristics

- 9 800 m^3 raw water reservoir.
- 8 sedimentation tanks with a storage capacity of 380 m^3 and 166 m^3/h output.
- 6 filters of 230 m^3/h capacity.
- 280 m^3 contact tank for disinfection.
- 2 000 m^3 treated water reservoir.

KORNOS WATER TREATMENT PLANT

Kornos Water Treatment Plant has been in operation since 1985. The nominal capacity of the Plant is 32 000 cubic metres per day with provision for extension to 48 000 cubic metres per day. The Plant treats raw water from the Lefkara and Dhypotamos dams. Water from the Kouris and Kalavasos dams can also be conveyed for treatment to Kornos Water Treatment Plant via the raw water reservoir of the Khirokitia Water Treatment Plant. Kornos Water Treatment Plant supplies water to the city of Nicosia.

Consulting Engineers:	- Rofe Kennard & Lapworth	
Contractors:		
Charilaos Apostolides & Co Ltd	- Civil Works	£ 1.171.261
Degremont Laing	- Electromechanical equipment	£ 771.105
Weir Pumps Ltd	- Pumping equipment	£ 683.576
Total Cost:		**£2.625.942**

Control room

Backwash of sand filters

Technical characteristics

- 8 000 m^3 raw water reservoir.
- 2 sedimentation tanks of 650 m^3/h capacity.
- 3 filters of 670 m^3/h capacity.
- 500 m^3 contact tank for disinfection.
- 8 000 m^3 treated water reservoir.

Aerial photograph of Kornos Water Treatment Plant and of the raw water reservoir.

LIMASSOL WATER TREATMENT PLANT

Limassol Water Treatment Plant has been in operation since 1994. The nominal capacity of the Plant is 40 000 cubic metres per day with provision for extension to 80 000 cubic metres per day. The Plant treats raw water from Kouris dam and it supplies water for drinking purposes to the city of Limassol, to the villages west of Limassol and the British Base of Akrotiri.

Consulting Engineers:	- Energoprojekt	
Contractors:		
Water Engineering Ltd	- Civil Works	£ 1.813.070
Water Engineering Ltd	- Electromechanical equipment	£ 4.438.148
Total Cost:		**£ 6.251.218**

General view of Limassol Water Treatment Plant

Sedimentation tanks

Technical characteristics

- Aeration tank.
- 3 sedimentation tanks of 570 m^3/h capacity.
- 6 filters of 360 m^3/h capacity.
- 8 000 m3 treated water reservoir.

TERSEPHANOU WATER TREATMENT PLANT

Tersephanou Water Treatment Plant has been in operation since October 1999. The nominal capacity of the Plant is 60 000 cubic metres per day with provision for extension to 90 000 cubic metres per day. The Plant treats raw water from the Kouris and Kalavasos dams through the Southern Conveyor pipeline. Desalinated water from the Dhekelia Desalination Plant can also be conveyed to Nicosia through the Tersephanou pumping station and the Tersephnou-Nicosia conveyor. Tersephanou Water Treatment Plant supplies water to the cities of Nicosia, Larnaca and Famagusta.

Consulting Engineers:	- Energoprojekt	
Contractors:		
Iacovou Brothers (Constructions) Ltd	- Civil Works	£ 3.150.000
Sigma Engineering Ltd	- Electromechanical equipment	£ 3.700.000
Caramondani Bros Ltd	- Pumping equipment	£ 820.000
Total Estimated Cost:		**£ 7.670.000**

Administration building

Flocculation, sedimentation and filtration tanks

Technical characteristics

- Aeration tank.
- 3 sedimentation tanks with a storage capacity of 375 m^3 and 833 m^3/h output.
- 8 filters of 400 m^3/h capacity.
- 16 000 m^3 treated water reservoir.

SELF CONTAINED WATER TREATMENT UNITS

For the supply of additional water to the Athienou area, two self contained water treatment units have been installed in 1996 with a nominal capacity of 250 cubic metres per day each. The units operate only during the period April to October.

Contractor:

Demos Taki & Sons Ltd - **£ 94.303**

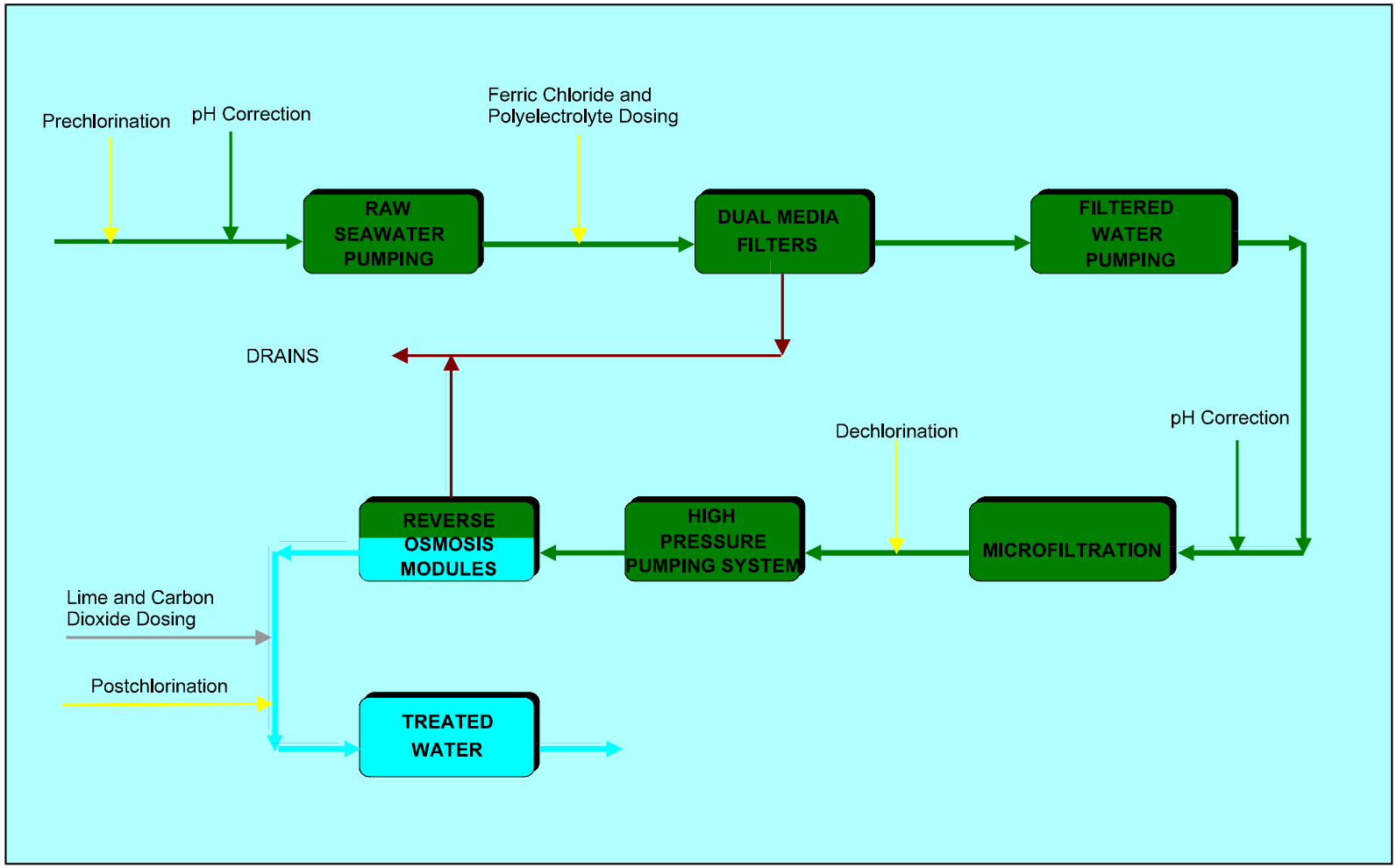
General view of Athienou water treatment units

Filters

Technical characteristics

- 20 m^3 raw water reservoir.
- 1 pressure filter of 10 m^3/h capacity.
- 1 small special filter of 0,5 m^3 capacity and 10 m^3/h output.
- 100 m^3 treated water reservoir (for both units).

FLOW DIAGRAM OF REVERSE OSMOSIS DESALINATION PLANT



DESALINATION SYSTEMS

GENERAL PRINCIPLES AND TREATMENT STAGES

Desalination systems have the ability to remove salts from sea water and produce fresh potable water. The major desalting processes are:

- **Thermal Distillation Processes**
  - Multi-stage Flash Distillation.
  - Multiple Effect Distillation.
  - Vapour Compression Distillation.
  - Solar Distillation.

- **Membrane Processes**
  - Electrodialysis.
  - Reverse Osmosis:
    a) with energy recovery,
    b) without energy recovery.

In *thermal distillation processes* saline water is heated to boiling point producing vapour, which is condensed, to form fresh water. For these processes, thermal energy is required, which can be produced by conventional or by renewable sources, such as solar energy. In *membrane processes*, electricity is required, either for water compression (70-80 atmospheres) or for ionisation of the sea water salts.

In comparison to *other desalting processes (distillation and electrodialysis)*, reverse osmosis is a relatively new method and has been used successfully since the early 1970s.

High pressure pumps

Reverse osmosis membranes

REVERSE OSMOSIS PROCESS

Reverse osmosis is a membrane separation process in which water from a pressurised saline solution is separated from the solutes by flowing through a membrane. For this separation no heating or phase change is necessary. The major energy required for desalting is for pressurising the feedwater of the membranes.

The basic stages of treating sea water in a reverse osmosis system are the following:

- Pretreatment
- Reverse Osmosis
- Posttreatment

1. Pretreatment

In reverse osmosis systems pretreatment of sea water is very important for the membranes. Therefore, in pretreatment stage micro-organisms must be destroyed and suspended solids must be removed so that micro-organism growth and salt precipitation does not occur on the membranes. Usually pretreatment of saline water consists of:

Microfilters

- Prechlorination of sea water
- Coagulation of colloid particles
- Fine filtration
- Acid addition (pH correction and inhibit precipitation)

2. Reverse Osmosis

At this stage, high pressure pumps supply the pressure needed to enable the water to pass through the membranes and reject the salts. This pressure ranges from 54 to 80 atmospheres. As a portion of the water passes through the membranes, in the remaining feedwater salt content increases. At the same time, a portion of this feedwater is discharged without passing through the membranes. Without this controlled discharge, the pressurised water would continue to increase in salt concentration, creating such problems as precipitation of supersaturated salts and increased osmotic pressure across the membranes. The amount of the feedwater discharged to waste is between 20 and 70 percent of feed flow and depends on the salt content of the feedwater.

3. Posttreatment

At the stage of posttreatment, water is stabilised and prepared for distribution.

This stage might consist of:

- Removal of gases, such as hydrogen sulphide.
- Adjustment of pH and hardness.

DHEKELIA DESALINATION PLANT

Dhekelia Desalination Plant is the first major desalination plant in Cyprus and utilises the reverse osmosis system.

Dhekelia Desalination Plant started operation on 1st of April 1997, with a nominal capacity of 20 000 cubic metres per day. Because of the prolonged drought the plant was immediately expanded and today has a nominal capacity of 40 000 cubic metres per day and provides water for the cities of Larnaca and Nicosia and the coastal tourist areas of Ayia Napa and Paralimni. The plant was commissioned on a built, own, operate and transfer basis (BOOT) and the desalinated water is sold to the Government, at source.

Seawater pumping station

Plant Operation

Sea water is pumped into the system through a 1200 mm diameter and 500 metres long pipeline. At the intake there is a screen to prevent fishes and sea plants to enter the pipeline. After chlorination with sodium hydrochloride and pH adjustment with sulphuric acid, seawater passes through a screen system and is then pumped to the main building which is located at an elevation of 17 metres above the sea.

Ferric chloride and polyelectrolyte are then injected into the system for coagulation and flocculation of the seawater colloids.

Seawater is then filtered through six gravity dual media filters made of gravel, silica and anthracite for the removal of all small solid matter above a certain size.

The filtered seawater is pumped to polypropylene wound cartridge filters. The purpose of these filters is to ensure that no particles with diameter of more than 1 μm can reach the membranes thus eliminating membrane fouling.

Before entering these filters, seawater pH is corrected and at the outlet the seawater is dechlorinated with sodium bisulphite for the protection of the reverse osmosis membranes.

The seawater is then pressurised by means of high pressure pumps and is fed to the reverse

osmosis membranes where it is desalinated. Each membrane train has a capacity of 5 000 cubic metres per day and consists of maximum 160 reverse osmosis membranes. The recovery is 50 percent.

The desalinated water is transferred to a tank where lime and carbon dioxide are added for pH correction and for increasing its hardness. Then it is postchlorinated and is delivered to a Water Development Department reservoir, 2 500 m3 capacity, from where it is pumped to the consumers.

Water quality control

Control room

Contractor:
Joint Venture CARAMONDANI BROS LTD & CARAMONDANI DESALINATION PLANTS LTD
Total Cost: US$29.000.000

Dhekelia Desalination Plant

Technical characteristics:

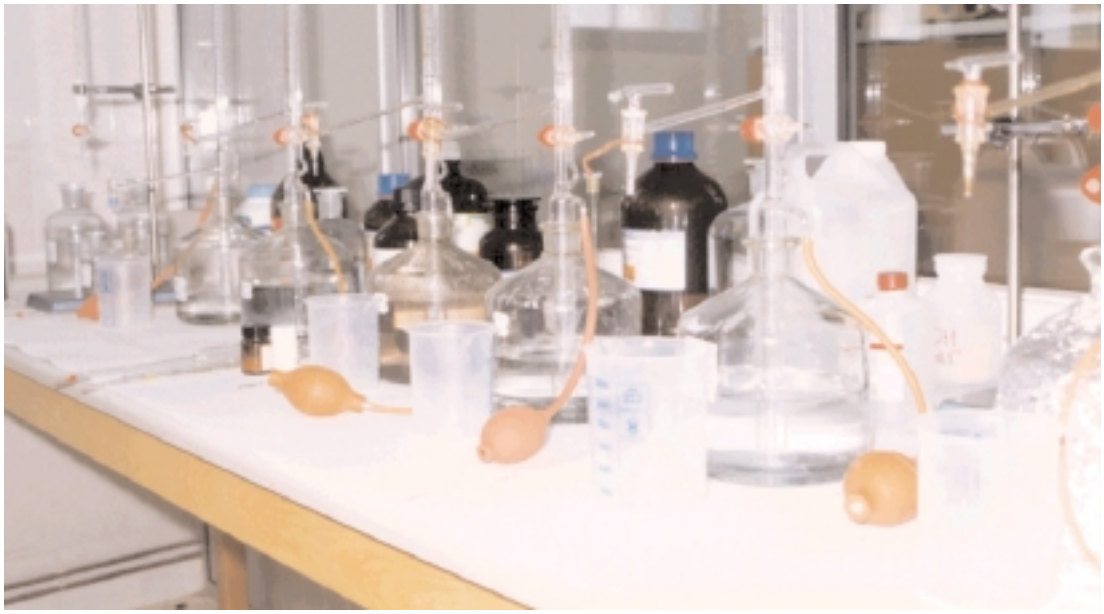
- Nominal daily capacity: 40 000 m3/day
- Nominal yearly capacity: 14 600 000 m3/yr
- Minimum daily capacity: 36 000 m3/day
- Minimum yearly capacity: 13 140 000 m3/yr
- Raw water source: Mediterranean Sea Water
- Intake system type: Open sea
- Total dissolved raw sea water solids: 40 570 mg/l
- Plant recovery: 50 percent
- Feed water hourly flow: 3 332 m3/h
- Product water hourly flow: 1 666 m3/h
- Product water total dissolved solids: <500 mg/l

QUALITY CONTROL

All the water treatment plants and the Dhekelia desalination plant have well equipped laboratories where Chemists/Chemical Engineers carry out chemical and bacteriological tests on both the raw and treated water so that the water produced is in accordance with EU Drinking Water Standards.

Furthermore well qualified personnel monitor on a 24 hour basis and at regular intervals the quality of the treated water.

In addition, water samples from the treatment plants and the desalination plant, are sent to the State General Laboratory for toxic, microbiological and other specific analyses.



Laboratory of Tersephanou Water Treatment Plant

Atomic absorption spectrometer for metals determination

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