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Hadera desalination plant two years of operation

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ABSTRACT

In May 2010, IDE Technologies Ltd. completed the Hadera plant, one of the world's largest operating seawater reverse osmosis desalination facilities. This was a milestone event for the desalination industry clearly confirming IDE's clear leadership of the mega-sized desalination market. IDE's design for the Hadera plant utilizes the three center design (pumping, membrane, and energy recovery centers), cascade boron treatment, and other technologies to decrease energy requirements and increase overall efficiency. These technologies have enabled Hadera to achieve one of the lowest ever costs for high-quality desalinated water. One of the main challenges met in the design of the plant was the minimization of the energy cost by utilizing the different electricity tariffs over a 24-h period, as well as a variable operation production regime. Moreover, the specific energy cost was further reduced by taking advantage of the common pressure center design during the peak electricity periods. Hourly variations in production from 100 to 40% are typical figures in day-to-day plant operation. The brackish reverse osmosis system patented cascade design demonstrates the system's ability to produce water with low boron content, minimum operational risks, and at the highest recovery ratios. The posttreatment system design is optimized to produce high-quality potable water in terms of the required alkalinity, hardness, pH and langelier saturation index through intensive rehardening, while still optimizing capital and operational costs. Recently the plant completed its second year of operation. This article describes the current plant operation section-by-section.

Keywords: Optimization; Energy cost; Energy consumption; Variable production regime; Electricity tariff

1. Introduction

The Hadera desalination plant, located in the Orot Rabin Power Station in Hadera, Israel, started its commercial operation in January 2010.

It is one of the biggest seawater desalination plants along the Mediterranean Sea and is a build, operate, and transfer project for 25 years, with shareholders IDE Technologies Ltd. (50%) and H&C (50%).

Although its original capacity was 100 M m^3/year, the plant was expanded to 127 M m^3 annually, from its first year of commercial operation.

During January 2012, the plant production was increased further, to 146 M m^3/year, in order to meet the needs for potable water in the area.

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2. Plant design: step-by-step

One of the key points of such large capacity desalination plants is their robustness and availability. According to the early stage bid requests of the state of Israel, the facility is divided into two independent plants, each capable of producing up to 9,750 m^3/h.

2.1. Intake

Seawater is pumped through three high density polyethylene (HDPE) pipes of 1,800 mm diameter each, from a distance of 1.25 km from shore. Each pipe is equipped with a suction head, located at a depth of 15 m, with a primary screen to prevent foreign obstacles from entering the main pipe and reaching the intake pit.

The pipes reach the three compartments of the intake pit which, under normal operation, are all interconnected. Whenever maintenance of one of the pipes is required, each of the compartments can be isolated by means of stop logs allowing the plant to continue its operation.

A reduction of dynamic water level inside the intake pit, due to barnacle growth on the intake pipes' inner walls, is a common phenomenon. As part of the plant's routine maintenance procedures, the pigging system, designed by IDE, is used three times a year to clean each of the HDPE pipes. The typical trend of level decrease in the pit over several months of operation can be seen in Fig. 1.

This pigging method is found to be efficient for controlling the growth of barnacles without the need for continuous or intermittent chlorination and is also implemented in other IDE plants such as Ashkelon and Larnaca.

In the intake pit, three self-cleaning rotating screens are installed prior to the intake pumps. Vertical turbine type intake pumps are used to pump the raw seawater toward the pretreatment area.

2.2. Pretreatment

If the intake system is essential to allow stable raw water supply to the plant, then the pretreatment design is the key factor for reliable reverse osmosis (RO) plant operation by supplying good quality water to the RO membranes.

One of the main challenges during the early stage of the engineering design was the limited area available. The dual media filtration (DMF) method was selected as the most suitable technically and economically for this plant. A unique configuration was adopted that minimizes the distance between the flocculation step and the dual media filters while maintaining optimum hydraulic distribution to the dual media cells. Due to this unique compact design, the overall plant footprint is minimized.

Chemicals are added in a static mixer prior to each of the pretreatment plants. The chemicals in use are ferric salts, while a polymer addition system is available but actually not in use.

Ferric salt dosage is controlled and monitored according to the seawater quality. This means the day-by-day optimization with jar tests in the laboratory, according to the raw seawater quality by the experienced plant operating personal.

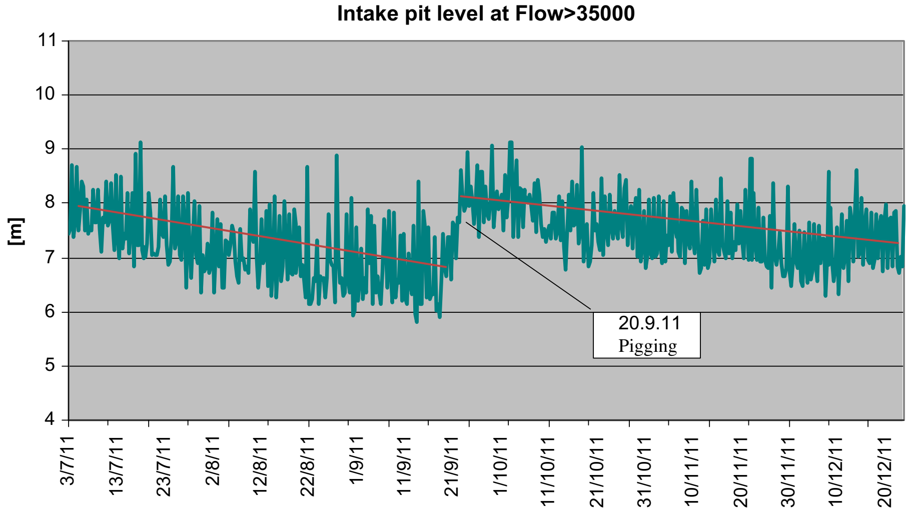


Fig. 1. Intake pit dynamic water level over time.

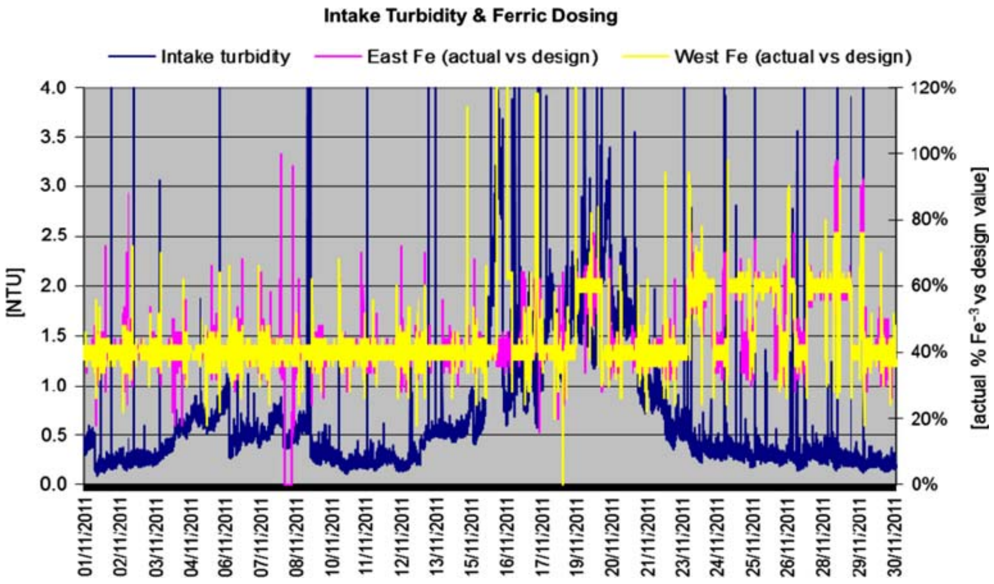


Fig. 2. Raw seawater turbidity vs. ferric^{+3} injection.

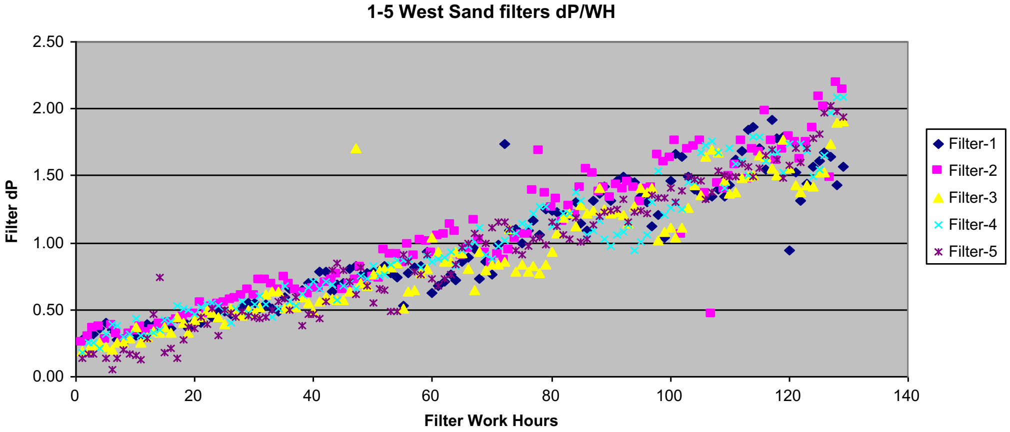


Fig. 3. Typical dual media filtration cycles.

As can be seen in Fig. 2, the actual ferric dosage is well below design value while still proportional to the raw water turbidity.

In total, there are 40 dual media filters in the plant. The media consists of sand and anthracite layers on top of concrete slabs equipped with typical PP filtration nozzles.

Fig. 3 represents typical DMF backwash cycles of 120–130 h.

After the DMF, gravity pulls the clear water to the clear water tank, where it is collected. A centrifugal pump is used to fill the backwash tank located just above the clear water tank and the backwash of each filter is achieved by gravity.

Fig. 4 depicts the filtrated seawater quality toward the membranes, which maintains a silt density index (SDI) of around three.

2.3. Cartridge filters

Filtrated seawater is pumped by horizontal centrifugal pumps from the clear water tank toward the cartridge filter vessels and thereafter, flow is divided to the HP booster pumps and the energy recovery system (ERS), respectively. Pressure is maintained at the minimum level required by the ERS system. Cartridge filters are of polypropylene melt blown type and are replaced periodically by the operating team. The

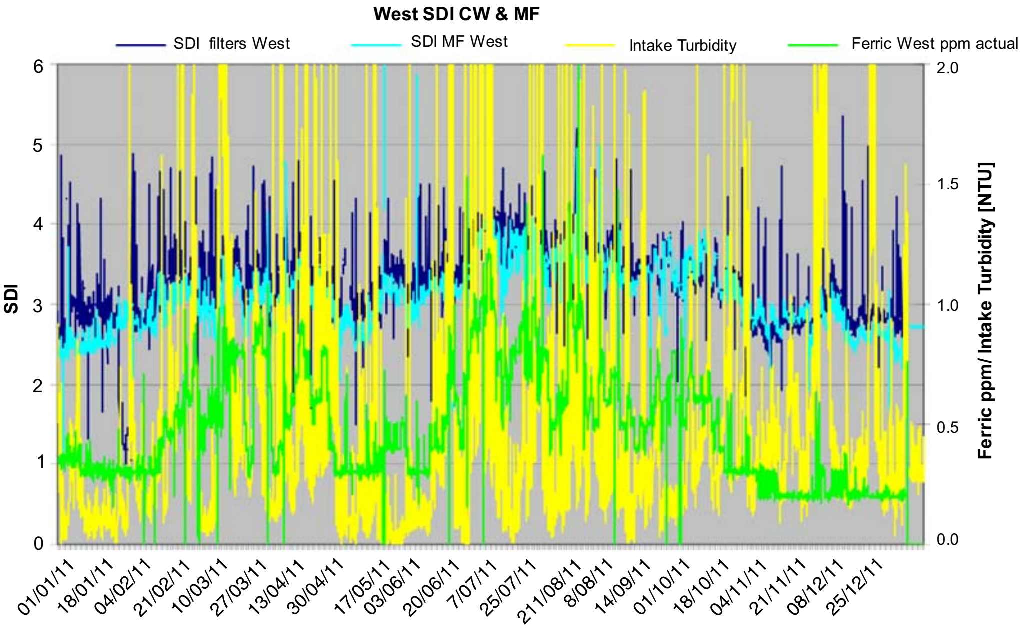
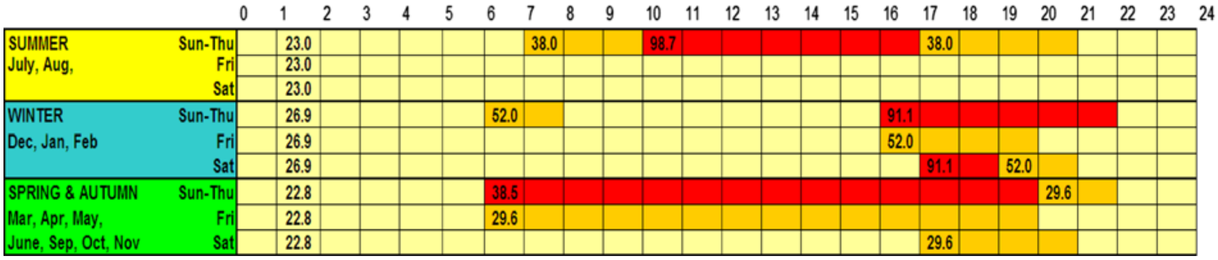


Fig. 4. SDI after multimedia filtration and micronic filters vs. time.



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July, Aug,	Fri		23.0																							
	Sat		23.0																							
WINTER	Sun-Thu		26.9					52.0	🟧									91.1	🟥	🟥	🟥	🟥	🟥			
Dec, Jan, Feb	Fri		26.9															52.0	🟧	🟧	🟧					
	Sat		26.9																91.1	🟥	52.0	🟧				
SPRING & AUTUMN	Sun-Thu		22.8					38.5	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	29.6	🟧			
Mar, Apr, May,	Fri		22.8					29.6	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧					
June, Sep, Oct, Nov	Sat		22.8																29.6	🟧	🟧	🟧				

Fig. 5. Variable energy tariff over the year.

replacement timing is determined by a trade-off between the replacement costs and pressure differential (energy losses).

2.4. Seawater reverse osmosis

The electricity cost in Israel is variable and depends on the period of the year and day of the week, as well as the hour of the day. The year is divided into three periods: summer, winter, and spring/autumn as presented in Fig. 5.

The cost varies from base tariff (the lowest off peak hours cost) to shoulder and peak hours as presented, in agorot*/kWh, in Fig. 6.

* 100 agorot = I NIS

Energy costs were analyzed using detailed plant models and the result of this analysis is the innovative operating model of the plant, which includes two main regimes during the day. The two daily regimes are high-load production during the base tariff and low-load production during the peak and shoulder hours.

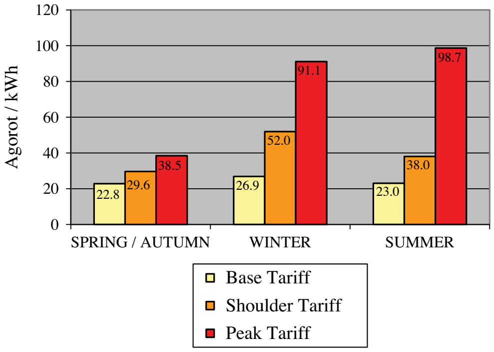


Fig. 6. Variable electricity cost.

The operation scenarios take full advantage of the pressure center design approach, in which the main high pressure pumps share a set of seawater reverse osmosis (SWRO) trains and ERSs.

These operation regimes decrease the specific energy cost per m^3 produced as they take advantage of the lower production rate, keeping most of the installed equipment in operation, and producing water at lower energy consumption. The lowest production regime is achieved by special purpose high pressure pumps.

As a result, during peak hours, both the electricity demand as well as the specific energy cost are reduced. Moreover, the plant availability is increased as some of the equipment is idle during the lower production rate regime.

As the seawater section has the highest energy demand, the rest of the plant production follows the governing production rate of the SWRO.

Overall plant energy consumption is below the warranted figure.

The key equipment components of the facility comprising the SWRO process are:

- A group of high pressure pumps working in parallel.
- Two special high pressure pumps (operating at low-load production regime).
- Racks of SWRO trains.
- Isobaric type ERSs, ERI, model PX-260.
- Approximately 40,000 seawater DOW Filmtec membrane elements.

Each subsystem is fully independent and can be maintained without shutting down any additional equipment. SWRO recovery is controlled by means of the variable frequency converters of the ERS booster pumps and is adjusted, per regime, to optimize the energy cost of the system making use of the variable tariff electricity cost.

2.5. The Brackish Water Reverse Osmosis: cascade system

The final water quality requires a maximum concentration of boron and chlorides of 0.3 and 20 ppm, respectively. As such, the SWRO pass permeate is split into front and rear permeate. The rear permeate with higher concentration is treated further in a second brackish water reverse osmosis pass operating at a high pH above 10. At this pH level, efficient boron rejection by the brackish elements is achieved, while the front permeate is mixed with the final product.

The Cascade configuration, an IDE patent, has been in use for several years at the Ashkelon plant. It is based on two additional passes. The third pass operates with the second pass brine at pH of around 9 to remove scale potential (in the form of calcium and magnesium ions and bicarbonate), while the permeate produced enters a fourth pass operating at high pH again to increase the boron removal of the brackish elements. The Cascade scheme is presented in Fig. 7.

2.6. Posttreatment plant

The final requested water quality, as presented in, demands a positive langelier saturation index (LSI) index and minimum alkalinity and hardness of 80 ppm Fig. 8.

These qualities are achieved by two main processes:

- The first is by partial rehardening with limestone reactors and CO_2 in order to receive the stoichiometric balance between alkalinity and hardness. As the rehardened water contains aggressive CO_2, pH adjustment is needed to reach the required final pH and LSI. This step is achieved in five limestone reactors.
- The second process includes the use of lime water instead of caustic soda. Lime water is less

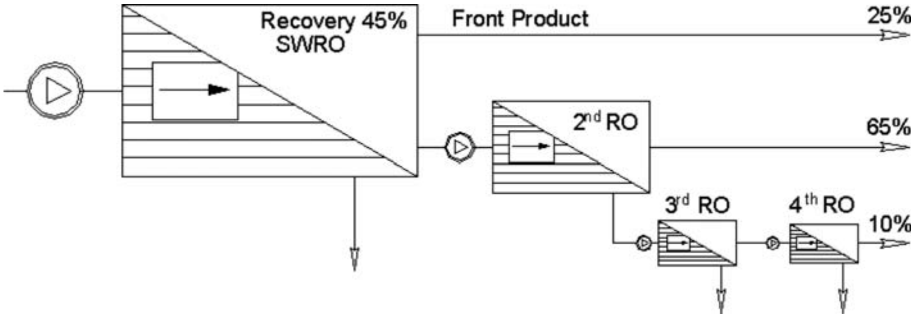
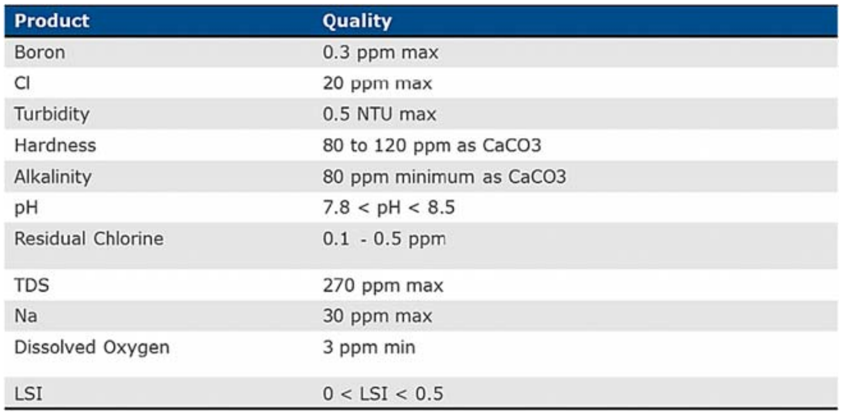


Fig. 7. Cascade design.

costly and slightly reduces the amount of calcium to be dissolved in the rehardened process as it contributes both to the calcium and to the alkalinity concentration in the final product. Lime water is produced by lime milk preparation from quick lime (CaO) and permeated water. One of the challenges of this system was to control its contribution to the final product turbidity and maintain it stable. During the commissioning and process optimization, this goal was achieved.



Product	Quality
Boron	0.3 ppm max
Cl	20 ppm max
Turbidity	0.5 NTU max
Hardness	80 to 120 ppm as CaCO3
Alkalinity	80 ppm minimum as CaCO3
pH	7.8 < pH < 8.5
Residual Chlorine	0.1 - 0.5 ppm
TDS	270 ppm max
Na	30 ppm max
Dissolved Oxygen	3 ppm min
LSI	0 < LSI < 0.5

Fig. 8. Final water quality.

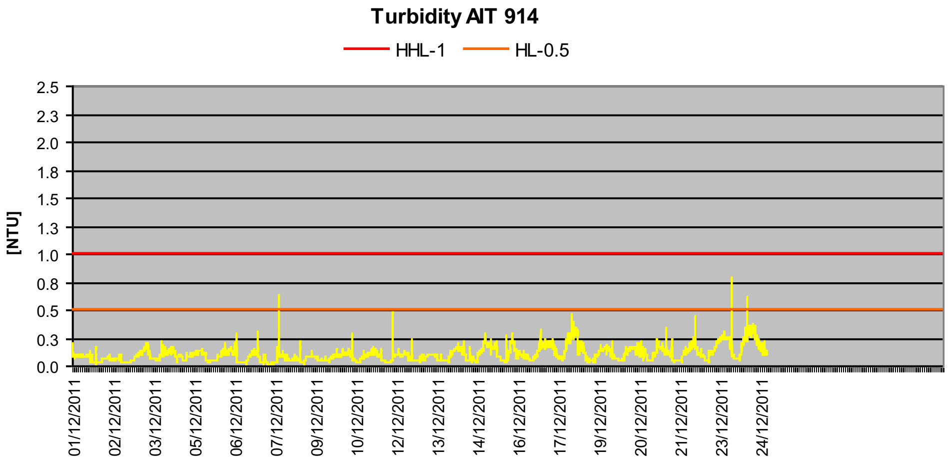


Fig. 9. Final product water turbidity.

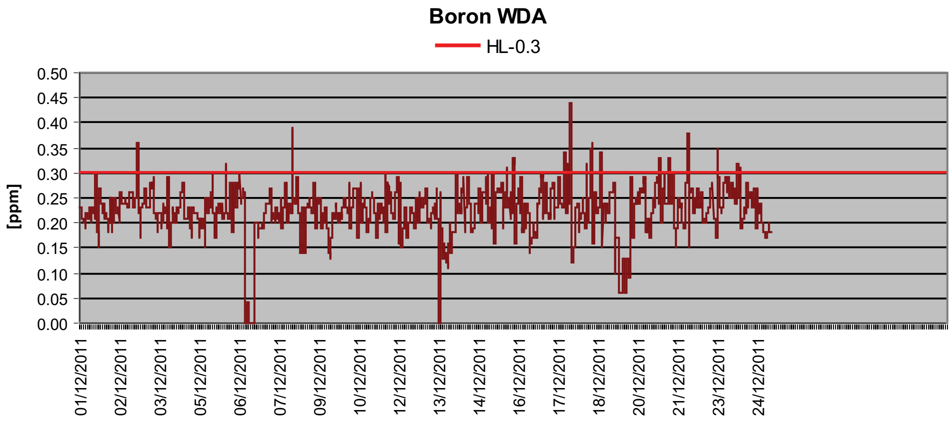


Fig. 10. Boron at final product.

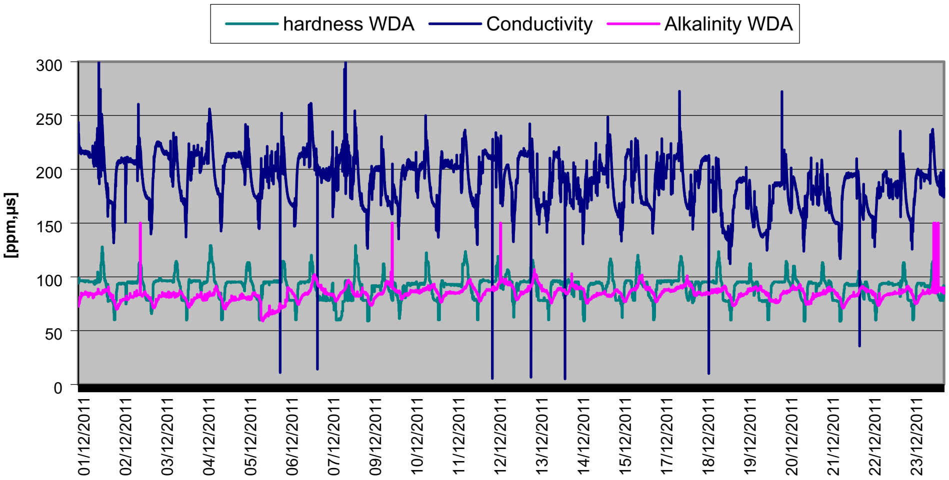


Fig. 11. Alkalinity, hardness, and conductivity of product water.

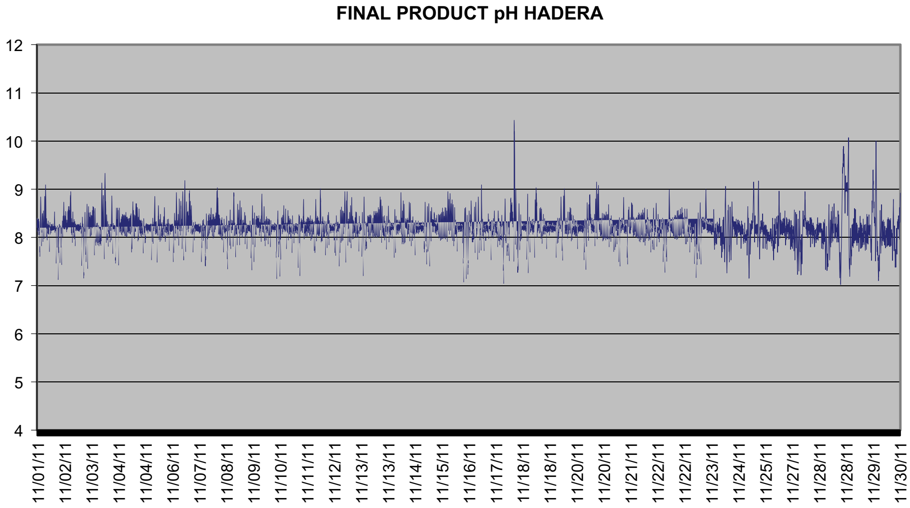


Fig. 12. pH of product water.

3. Product quality

Figs. 9–12 represent the typical final product water quality in the plant during one month of operation.

4. Brine and backwash to the sea

Brine from the desalination facility is mixed with the cooling water stream used in the adjacent Orot Rabin power plant.

Backwash water from the dual media filters is collected in a holding tank and later released in a controlled manner to the overall brine stream to the sea. The stream is monitored continuously in terms of conductivity, turbidity, and pH.

5. Current plant expansion

The annual production bell of 127 M m^3/year plant is presented in Fig. 13.

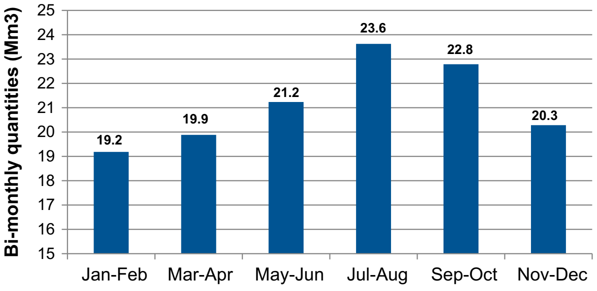


Fig. 13. Bell curve of annual production per two month period—127 M m^3/year.

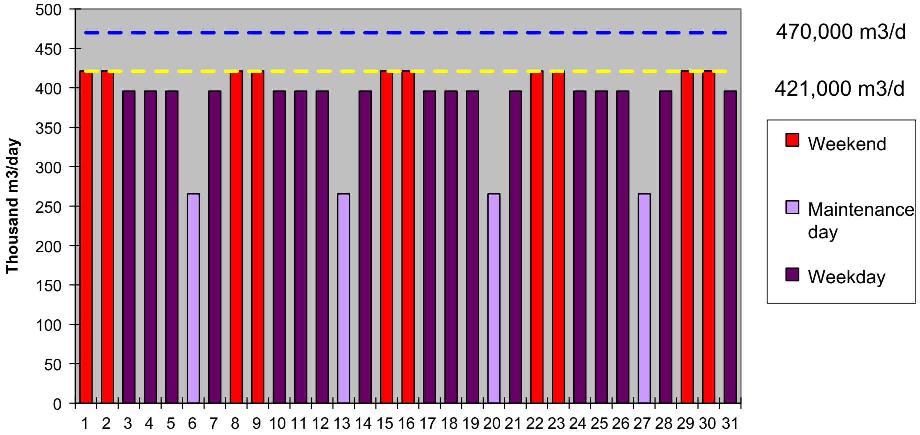


Fig. 14. Daily production—July 2011.

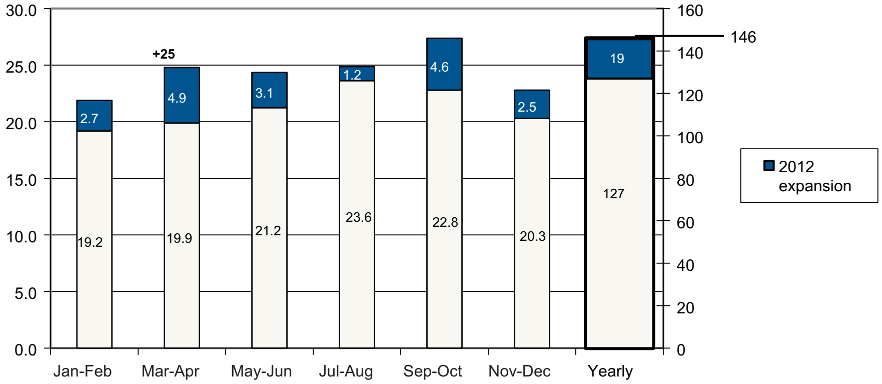


Fig. 15. Increased plant production.

The production capability of the whole facility would be higher if it operated constantly at maximum production throughout the day year round (see Section 2.4).

This fact is illustrated in Fig. 14, representing July 2011 production.

Recently, due to a demand from the state of Israel, an agreement was reached to increase production to a total of 146 M m^3 annually for the next two years. This annual production rate is still below the plant's maximum capabilities, which can be further explored in the future (Fig. 15).

6. Conclusions

The Hadera plant recently completed two years of commercial operation.

Its sophisticated design allows the plant to reach low energy cost, based on Israel's grid electricity tariff, while taking best advantage of the equipment installed.

The plant design, while sophisticated, is based on simple and standard equipment blocks, already used in previous IDE plants.

The plant produces potable water in a stable and reliable way, within the expected quality parameters, and allows future expansion by simple update of the operating regime.

Acknowledgments

Special thanks to OMIS plant Manager Mr. Dany Winkler, the O&M company operating the plant and Ms. Dorit Yaron and Ms. Faina Bortnick for their continuous support and supply of plant operational data.