

# SUSTAINABLE DESALINATION: ENVIRONMENTAL APPROACHES

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## **Abstract**

The environmental issues of possible concern during construction and operation of desalination plants (mainly large-scale facilities) include impacts that are common to many coastal development projects (e.g. land use and aesthetic impacts), as well as specific impacts associated with the elements of the desalination system and auxiliary infrastructure. In the latter category these relate to the introduction of highly saline brine and process additives to the marine environment, and to the emission of greenhouse gases and air pollutants due to the energy demand of the desalination process. Other environmental issues of possible concern must be considered, such as entrainment and impingement of marine organisms from the intake of seawater, hazards associated with storage and use of various chemicals, noise, etc. Most of the potential environmental impacts during construction and operation of desalination facilities are of a local nature. The potential environmental impacts during operation are mostly continuous, while those associated with construction activities are temporary and mostly reversible.

IDE strives to conduct its business with responsibility towards the environment and promotes the use of environmentally friendly technologies and approaches, avoiding or mitigating potential environmental impacts. The specific mitigation measures represent the ‘state-of-the-art’ with respect to environmental management of desalination facilities and ensure compliance with applicable environmental legislation.

This paper assesses the potential environmental impacts on the marine and terrestrial environments, as well as on the atmosphere, at both construction and operation stages of large-scale desalination facilities, and describes the solutions implemented at IDE’s largest and most modern facility in Sorek (150M m<sup>3</sup>/y – 624,000 m<sup>3</sup>/d), which have been classified as the “best available technology”, on the management of the potential environmental impacts.

Field experience results of several monitoring programs on the marine environment in the proximity of large scale desalt plants in Israel and Australia is also assessed.



## **I. INTRODUCTION**

Global depletion of water sources and water scarcity are serious problems that are affecting municipal health and industry in an increasing number of regions throughout the world. In many countries the lack of water resources also acts as a limiting factor affecting the development and growth of their economic sectors, thus affecting countries' GDP.

As seawater desalination technologies have matured over the past four decades, seawater desalination is being increasingly utilized by both governmental agencies and industry as a sustainable solution to the lack of usable water.

While the social and economic benefits of desalination are recognized, scientific and public concerns are raised over potential adverse impacts of desalination on the environment. Key concerns are the energy demand to drive the process and the emission of greenhouse gases. Impacts associated with land use, construction activities, intake and the related effects of concentrate discharge are also among the main issues raising public awareness.

The desalination industry is focused today on incorporating sustainability aspects and mitigation measures into the design and operation of desalination plants, rising to the challenge to reduce the environmental footprint of desalination facilities and recognizing effective environmental management that also brings potential economic benefits.

The potential environmental impacts on the marine and terrestrial environments, as well as on the atmosphere, at both construction and operation stages of large-scale desalination facilities are analyzed in this paper, which also describes various measures and approaches aimed at avoiding, mitigating or minimizing these potential environmental impacts. Field experience results of several monitoring programs held on the marine environment in the proximity of large scale desalt plants in Israel and Australia is also assessed.

## **II. ENVIRONMENTAL ISSUES OF POSSIBLE CONCERN**

The environmental issues of possible concern (potential environmental impacts) during construction and operation of SWRO facilities include impacts that are common to many coastal development projects (e.g. land use and aesthetic impacts), as well as specific impacts associated with the elements of the desalination system and the auxiliary infrastructure. The main issues of possible concern in the latter category are related to the introduction of highly saline brine and process additives to the marine environment, and to the emission of greenhouse gases and air pollutants due to the energy demand of the desalination process. In addition, various other environmental issues of possible concern must be considered, such as entrainment and impingement of marine organisms from the intake of seawater, hazards associated with storage and use of various chemicals and more. Most of the potential environmental impacts during construction and operation of SWRO facilities are of a local nature. The potential environmental impacts during operation are mostly continuous, while those associated with construction activities are mostly temporary and reversible.

The potential environmental impacts of a desalt plant during the construction and operation stages are presented in Tables 1, 2 and 3 below.

The Tables include estimates of the spatial extent of each potential environmental impact under the assumption that no impact mitigation measures have been adopted. This classification, based on the evaluation in UNEP (2008), gives an indication of the significance of each impact and consequently of the significance of the planned mitigation measures presented in Section III. The spatial scales are defined as follows:

- Localized = punctual, within the area of the project site, within 100m of origin;  
 Mid-range = within the project site and nearby areas, within 1,000m of origin;  
 Far range = effects beyond project site and nearby areas, beyond 1,000m of origin.

**Table 1: Potential Environmental Impacts - Construction Stage**

<b>Potential Environmental Impact</b>			
<b>Impact</b>	<b>Location</b>	<b>Spatial extent</b>	<b>Source of impact</b>
Alteration of the natural terrain	Onshore	localized	Earth works, construction works
Impacts of construction wastes and excess soil	Onshore & Offshore	localized	Earth works, construction works
Soil and groundwater pollution (fuels, oils, etc.)	Onshore	localized	Earth works, construction works
Air pollution (fugitive dust emission)	Onshore	mid-range	Earth works, construction works
Noise emission	Onshore	mid-range	Earth works, construction works
Damage to antiquities	Onshore & Offshore	localized	Earth works, construction works
Alteration of the seabed	Offshore	localized	Marine works
Sediment resuspension (impacts on marine water quality and ecology)	Offshore	localized to mid-range	Marine works
Oil pollution	Offshore	localized to far-range	Marine works

**Table 2: Operation Stage –Potential Impacts on the Marine Environment**

<b>Potential Environmental Impact</b>		
<b>Impact</b>	<b>Spatial extent</b>	<b>Source in the Facility</b>
Habitat alteration and changes in sediment transport	localized	Intake & outfall systems (piping)
Entrainment and impingement of marine biota	localized to mid-range	Intake system (suction heads)
Debris pollution (from intake screening)	localized	Intake system (screening system)
Biological effects of residual chlorine & chlorination by-products	localized to mid-range	Intake system (biofouling control)
Biological effects of increased seawater salinity	localized to mid-range <sup>1</sup>	Concentrate outfall (RO brine)

<sup>1</sup> Refers to > 5% salinity change compared to ambient salinity.

<b>Potential Environmental Impact</b>		
<b>Impact</b>	<b>Spatial extent</b>	<b>Source in the Facility</b>
Effects of residual chemicals (iron-hydroxide, metals, antiscalants, membrane cleaning chemicals) and particulate matter in the concentrate <sup>2</sup> (biological & aesthetic impacts)	localized to mid-range	Concentrate outfall (process streams)

**Table 3: Operation Stage – Potential impacts on the terrestrial environment and atmosphere**

<b>Potential Environmental Impact</b>		
<b>Impact</b>	<b>Spatial extent</b>	<b>Source in the Facility</b>
Alteration of the coastal environment and obstruction of free passage along the seashore	Localized	Onshore pipelines and pumping station
Emission of greenhouse gases and air pollutants	Mid- to far-range	Power generation
Noise emission	Mid- to far-range	Pumping station and main plant
Light “pollution”	Localized	Main plant
Accidental spillage or leakage of hazardous chemicals	Localized to mid-range	Main plant (storage & handling of chemicals)
Solid waste and sanitary sewage	Localized	Main plant (used containers, maintenance works wastes, office wastes, sanitary sewage)
Aesthetic impacts (landscape and natural scenery)	Localized to mid-range	All inland structures

### **III. ENVIRONMENTAL MITIGATION MEASURES**

#### **3.1. Overview**

IDE’s mitigation measures aimed at avoiding or minimizing the potential environmental impacts in its mega-size projects are tailored according to each site and its boundary conditions. This section presents the solutions implemented at IDE’s largest and most modern facility in Sorek (150M m<sup>3</sup>/y – 624,000 m<sup>3</sup>/d), which have been classified “state-of-the-art” and constitute the “best available technology” on the management of the potential environmental impacts listed in the previous section.

The environmental mitigation principles underpinning the specific mitigation measures adopted in the design, construction and operation of IDE’s Sorek mega-plant include employment of environmentally-friendly construction methods; rehabilitation of areas affected during construction, and; design assuring minimal alteration of the natural environment, minimal energy consumption and minimal use and discharge of process chemicals. The specific mitigation measure depicted for each impact ensures compliance with the requirements of the applicable environmental legislation.

<sup>2</sup> In this document “concentrate” means the RO brine and the process streams discharged to the sea with the brine.

Routine environmental monitoring, as applicable in IDE’s large-scale desalination facilities, is envisaged to be applied in Sorek in order to verify the impact assessments associated with the operation of the facility and to trigger additional mitigation efforts if necessary.

### 3.2. Mitigation Measures - Construction Stage

Table 4 presents mitigation measures adopted for avoiding or minimizing environmental impacts during construction of the Sorek facility. Following the table, a succinct description of the most significant mitigation measures is provided.

**Table 4: Construction Stage - Mitigation of Potential Environmental Impacts**

Potential Environmental Impact		Mitigation Measures	Section in this document
Impact	Source of impact		
Alteration of the natural terrain (land area)	Earth and construction works	Pipe-jacking (tunnelling) for installation of onshore pipelines (seawater feed and brine)	3.2.1
		Rehabilitation of grounds used as temporary organization areas during construction	3.2.2
		Measures for soil retention in plant area	-
Impacts of construction wastes and excess soil	Earth and construction works	Recycling of construction wastes and use or authorized dumping of excess soil	3.2.3
Soil and groundwater pollution (fuels, oils, etc.)	Earth and construction works	Placement of fuel/oil tanks in containment basins; special care during fuelling operations; collection and proper disposal of used lubricating oils	-
Air pollution (fugitive dust emission)	Earth and construction works	Surface wetting; covering of loaded trucks exiting work areas	-
Noise emission	Earth and construction works	Limits on working hours and on noise emission from construction equipment as required by law	-
Damage to antiquities	Earth and marine works	Actions as prescribed by Antiquities Authorities	3.2.4
Alteration of the seabed	Marine works	Pipe-jacking for installation of offshore pipelines (intake & outfall) to at least 600m from the shoreline; precisely controlled dredging for installation of pipelines from 600m; covering of the pipelines and restoration of the original bathymetry	3.2.1

Potential Environmental Impact		Mitigation Measures	Section in this document
Impact	Source of impact		
Sediment resuspension	Marine works	Minimal dredging activities; minimization of drifting and sweeping of dredger suction head by precise positioning control	3.2.1
Oil Pollution	Marine works	Prevention of oil pollution from vessels	-

*3.2.1 Installation of offshore and onshore pipelines by pipe-jacking and limited, precisely controlled dredging at sea* - Offshore intake and outfall pipelines, within the breaker zone and to a distance of at least 600m from the shoreline, and the onshore connecting pipelines to the pumping station are installed by pipe-jacking, a well proven tunnelling method for the installation of underground pipelines. This method, illustrated in Figure 1, avoids the environmental problems commonly associated with traditional open cut trenching. Specifically, use of this method does not cause any alteration of the natural coastal terrain; avoids disruption of coastal ecosystems; saves the need for erecting a cofferdam at the beach, and minimizes disturbance of the marine environment, including sediment resuspension. The dredged material is stored at an authorized site at sea and, upon completion of the pipeline installation, is used for covering the pipes (backfill) and restoration of the original bathymetry.

Spoils from the pipe-jacking process, removed through the start pits, is managed as follows: marine material is returned to the sea subject to authorization and in accordance with applicable law; terrestrial material is either dumped at sea (if found suitable) subject to authorization, or used as material for batteries around Facility site. Upon completion of the pipe-jacking works, the onshore start pit is covered with a roof 1m below the natural soil level, and the entire area is restored to its original state.



**Figure 1: Illustration of Pipe-Jacking Method**

3.2.2. *Rehabilitation of grounds used as temporary organization areas* - Temporary organization areas during construction include areas for temporary office, storage, logistics and a special area allocated for various forms of construction waste. Upon completion of the construction works, all temporary organization areas are rehabilitated: the areas are cleared (buildings and materials dismantled and removed), the compact aggregates and concrete wastes are recycled (Section 3.2.3 below), and the original topography is restored as feasible.

3.2.3. *Recycling of construction wastes and use of excess soil* - Waste materials from construction of the facility are recycled. Compact aggregates from temporary organization areas are reused for the first layer under the roads of the site. Concrete wastes and stones are crushed and recycled to be used as the under-layer of the site's roads. Steel is collected and removed from the site to be recycled. Plastic and wood are removed and recycled off-site. Excess and leftover soil from digging and piping works is used for leveling the site to the desired elevation, and can also be used as material for batteries around the site.

3.2.4. *Prevention of damage to antiquities* - Actions to preserve and prevent damage to antiquities during the construction stage are as prescribed by the local competent Antiquities Authority ("the Authority"). Since parts of the areas designated for the plant and associated infrastructure facilities were "Declared Antiquities Sites", a preliminary antiquities survey was conducted and findings were properly removed. Furthermore: (a) all earthworks were carried out in the presence of an inspector representing the Authority and according to the inspector's instructions regarding preservation and prevention of damage to antiquities; (b) in the event of antiquities discovered on land or at sea, actions were coordinated with the Authority.

### 3.3. Mitigation measures - Operation Stage

Table 5 and Table 6 present the mitigation measures incorporated in the Sorek plant design for avoiding or minimizing environmental impacts during operation. Following the tables, a succinct description of the most significant mitigation measures is provided.

**Table 5: Operation Stage - Mitigation of potential environmental impacts on the marine environment**

Potential Environmental Impact		Mitigation measures	Section in this document
Impact	Source of impact		
Marine habitat alteration and changes in sediment transport	Intake & outfall systems (piping)	Intake and outfall pipelines laid below the seabed	3.3.1
Entrainment and impingement of marine biota	Intake system (suction heads)	Intake heads designed for slow suction velocity	3.3.3
Debris pollution	Intake system (screening system)	Self-cleaning traveling screen for debris collection; disposal of collected debris in authorized waste disposal sites	3.3.4
Biological effects of residual chlorine & chlorination by-products	Intake system (biofouling control)	Chlorine dosing (shock treatment) into the intake in the direction of the plant, avoiding chlorine	-

Potential Environmental Impact		Mitigation measures	Section in this document
Impact	Source of impact		
		discharge to the sea	
Biological effects of increased seawater salinity	Concentrate outfall (RO brine)	Outfall diffuser system designed to enhance initial dilution of concentrate	3.3.5
Effects of residual chemicals (iron-hydroxide, metals, antiscalants, membrane cleaning chemicals) and particulate matter in the concentrate (biological & aesthetic impacts)	Concentrate outfall (process streams)	Minimal use of chemicals (process additives)	3.3.6
		Land-based treatment of dual-media filter backwash prior to discharge and disposal of the sludge in authorized waste disposal sites	3.3.7
		Use of environmentally harmless antiscalants	3.3.8
		Treatment of limestone reactors washings together with dual-media filters backwash	3.3.9
		Use of inorganic solutions only for membrane cleaning and neutralization of cleaning solutions prior to discharge	3.3.10

**Table 6: Operation Stage - Mitigation of potential environmental impacts on the atmosphere and land area**

Potential Environmental Impact		Mitigation measures	Section in this document
Impact	Source of impact		
Alteration of the coastal environment and obstruction of free passage along the seashore	Onshore pipes and pumping station	Interconnecting pipelines (intake & outfall) laid underground; pumping station located inland at plant site	3.3.2
Emissions of greenhouse gases and air pollutants	Power generation	Minimal energy consumption; power plant fuelled by natural gas as the main source of energy; capture of CO <sub>2</sub> from gas burning and its use during the post – treatment stage	3.3.11
Noise emission	Pumping station and main plant	Acoustic insulation of the Facility structures	3.3.12
Light “pollution”	Main plant	Minimal external lighting; minimal light “spillage” onto areas beyond Facility site	-



Potential Environmental Impact		Mitigation measures	Section in this document
Impact	Source of impact		
Accidental spillage or leakage of hazardous chemicals	Main plant (storage & handling of chemicals)	Safety measures for transportation, storage and handling of chemicals as prescribed in applicable legislation; placement of storage tanks for corrosive chemicals in secondary basins; chemical neutralization of any spill prior to disposal	3.3.13
Solid waste and sanitary sewage	Main plant operations	Waste segregation; containers for solid waste collection; waste disposal in authorized sanitary landfills; waste recycling as feasible; proper disposal of sanitary sewage	3.3.14
Aesthetic impacts (landscape and natural scenery)	All inland structures	Architectural	3.3.15

3.3.1 *Laying of offshore intake and outfall pipelines below the seabed* - Laying the intake and outfall pipelines below the seabed avoids all environmental impacts that may occur if the pipelines were to be placed on the seabed (i.e. creation of artificial hard-substrate habitats; changes in sediment transport patterns and erosion phenomena)<sup>3</sup>.

3.3.2. *Laying of onshore pipelines underground and location of pumping station far from the shoreline* - Laying the on-shore interconnection pipelines (seawater and brine) underground, and location of the pumping station at the main plant site 2.2 km away from the shoreline, prevents any permanent alteration of the coastal environment and any obstruction of free passage along the seashore.

3.3.3. *Intake suction heads designed to minimize entrainment and impingement effects* - In order to minimize entrainment and impingement of biota from the intake of seawater<sup>4</sup>, the design of the intake suction heads assures a slow suction velocity of 0.15 m/sec, comparable to normal ambient sea currents. Such velocity is slow enough to allow virtually all mobile organisms (e.g. fish, large crustaceans) to swim away from the intake and avoid impingement, as well as to minimize the potential for entrainment of drifting small biota (plankton, fish eggs, larvae)<sup>5</sup>. Therefore, significant ecological losses to source populations of the entrained/impinged species are not expected.

3.3.4. *Collection and disposal of marine debris* - Self-cleaning traveling screens are installed at the intake pit to eliminate debris. The removed debris is collected into dedicated containers for eventual disposal in authorized waste disposal sites.

<sup>3</sup> The intake heads and outfall diffusers which are located above the seabed are not expected to influence sediment transport.

<sup>4</sup> Entrainment occurs when intake pipes take in small aquatic organisms, including plankton, fish eggs, and larvae, with the intake water. Impingement is the pinning and trapping of fish or other larger organisms against the screens of the intake structures.

<sup>5</sup> The US Environmental Protection Agency recognizes reduction of intake flow velocity to 0.152 m/sec (0.5 feet/sec) or less, as *Best Technology Available* for impingement reduction.

*3.3.5 Outfall designed to enhance initial dilution of concentrate* - In order to minimize the spatial extent of the area affected by the concentrate discharge (salinity and residual chemicals), a specially designed diffuser has been installed at the outlet of the concentrate outfall. The detailed design, aimed to enhance rapid initial dilution of the concentrate, takes into account the local hydrographical and meteorological conditions, as well as the results of Far and Near Fields Marine Dispersion Models.

*3.3.6 Minimal use of chemicals* - The use of chemicals in reverse osmosis desalination plays a main role in the membrane separation process, especially when low Boron concentration is required. In Sorek, the types of chemicals used are restricted to those imperative for reaching the final product quality, those intended for process enhancement, or those required to ensure proper operation. As a rule, all chemicals used have no/low environmental impact upon discharge, and are approved for their intended use by regulatory agencies.

Based on IDE's extensive experience in the operation of large-scale desalination plants, an optimal design for the types and consumption rates of chemicals has been reached. The efficiency of each process stage in which chemical treatment is necessary has been improved in order to minimize chemical consumption.

In pre-treatment stages, a flocculation chamber is implemented before gravity filtration for the slow mixing of a minimal dosage of coagulant following the formation of large and strong flocs that can then easily be removed by the filtration media<sup>6</sup>.

The use of antiscalants has been optimized based on actual water chemistry data and long-term trials performed at existing plants with different products for the optimization of chemical dosing. Furthermore, innovative approaches are continuously adopted to improve the efficiency of chemical consumption at the post-treatment stage, with the potential application of the absorption/desorption processes for the re-use of excess CO<sub>2</sub>.

*3.3.7 Land-based treatment of dual-media filters backwash* - Common practice nowadays consists of land-based treatment of the backwash of dual-media filters to reduce the marine discharge of particulate matter and residues of process chemicals. The treatment process, designed to achieve removal of ~90% of the suspended solids retained at the filters, comprises flocculation, sedimentation, thickening and a final sludge de-watering process. The stabilized sludge (at least 25% dry solids and less than 6% dissolved solids) is disposed of in an authorized waste disposal site. The clarified water is discharged to the sea with the brine stream.

The untreated backwash contains particulate matter and heavy metals that occur naturally in the intake water, iron-hydroxide (Fe(OH)<sub>3</sub>) flocs formed upon contact of the coagulant with the intake water, and minute quantities of heavy metals from impurities in the coagulant. At the prevailing pH in the system, most metals in the backwash will be adsorbed onto particulates and removed by the backwash treatment process. Considering the envisaged use of coagulants, the efficiency of the backwash treatment and the dilution ratio of the residual liquid (clarified backwash) with the RO brine stream, iron concentrations in

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<sup>6</sup> In cases where no flocculation is implemented, large quantities of chemicals are required in order to reach comparative results.

the concentrate discharged to the sea do not exceed 0.3 mg/l on a monthly average and 0.5 mg/l at any given time. This prevents discoloration of the receiving waters (i.e. the potential aesthetic impact associated with higher concentrations of iron-hydroxide). The level of other heavy metals in the concentrate is well below international water quality criteria for the protection of marine life [1,2,3]. Consequently, even in the initial mixing zone at sea, metal concentration levels are below those causing environmental concern.

*3.3.8 Use of environmentally-harmless antiscalants* - Antiscalants envisaged for use in the facility are based on Poly-Phosphonate or other suitable substances. Phosphonates are used extensively as anti-scaling agents in SWRO facilities worldwide, without regulatory restrictions, as these substances are considered harmless to the marine environment (being non-toxic to marine organisms at applicable dosing levels and having low biodegradability rate, typically less than 20% in 30 days). Nevertheless, use of phosphorus-free or low-phosphorus antiscalants shall be considered, should such substances, which have been previously proven successful in the RO process as well as harmless to the marine environment, be available.

*3.3.9 Treatment of backwash from limestone reactors* - Limestone reactors are backwashed with the brine of the “polishing” stage. The backwash water is blended with the backwash water from the pretreatment gravity filters at the sludge treatment unit. This enhances the thickening and neutralization of the sludge, and prevents peaks of high TSS and turbidity levels in the concentrate discharged to the sea, which might occur if the backwash from the limestone reactors were to be discharged untreated into the brine stream.

*3.3.10 Use and neutralization of inorganic membrane cleaning solutions* - Caustic Soda and Hydrochloric Acid used for membrane cleaning are neutralized (to produce NaCl) prior to discharge into the brine stream. No organic chemicals are used for membrane cleaning.

*3.3.11 Minimal emissions of greenhouse gases and air pollutants* - Emissions of greenhouse gases and air pollutants are minimized by implementation of the following strategy:

- Minimal energy consumption - innovative design approaches, state-of-the-art technologies and the accumulated experience of other large-scale plants have been combined to reduce the energy consumption to a minimum. The following main features were implemented: design optimization and recovery yield of the RO system; optimization of facility hydraulic profile; highest efficiencies in pumps and motors; introduction of variable-frequency drive devices in critical stations; major efficiencies at the high-pressure Energy Recovery Device, and implementation of the Pressure Center and “cascade” concepts.
- Use of natural gas as the main source of energy for power generation.
- Capture of CO<sub>2</sub> from the burning of natural gas and its use for limestone dissolution during the post-treatment stage is envisaged to be implemented in the future. The technology is based on capture and purification of CO<sub>2</sub> from the burning gas and its direct mixing with permeate water through an absorber column upstream of the limestone reactors, for the final re-hardening of the product water.

*3.3.12 Minimal noise emission* - The detailed design of the facility and equipment selection assures that maximum noise levels at sensitive noise receivers does not exceed the limits specified in relevant noise regulations.

Common mitigation measures with regard to noise emission include:

- All machinery is located inside industrial structures with nominal sound reduction of ~27 dB, or as determined during the detailed design process.
- The industrial structures were carefully designed, taking into account ventilation requirements and all other openings required for normal operation procedures.
- Service and access doors provide nominal sound reduction of ~22 dB nominal, as determined during detailed design process.
- Ventilation openings were designed to minimize noise radiation, and silencers are used, whenever necessary, to ensure that all noise criteria are met.

*3.3.13 Prevention and control of chemical leakage and spillage* - Management of chemicals (transport to the site, and storage and handling of chemicals in the facility) is in accordance with the applicable legislation, taking into account the recommendations of risk assessment for dangerous substances performed. A defined area at the plant is designated for chemical storage. Storage tanks for corrosive liquids are placed into secondary containment basins of adequate capacity, lined with anticorrosive material. In case of any accidental spillage, the liquid will remain within the basin until it is neutralized and disposed of properly. The Standard Operation Procedures of the facility include specific procedures for storage, handling, and disposal of chemicals, as well as for incident management including spill control and clean-up measures.

*3.3.14 Solid waste and sanitary sewage collection and disposal* - All operational solid waste (used containers, wastes from routine maintenance works, office waste etc.) is segregated as appropriate, stored in suitable containers and disposed of in authorized waste disposal sites or sent for recycling, as feasible.

The sanitary sewerage system is designed and executed according to standards and applicable regulations. The various branches of the sanitary sewer are connected to a main collector that is evacuated on a regular basis, or treated by a small compact sewage treatment unit and reused for garden irrigation.

*3.3.15 Landscaping and visual aesthetics* - Preservation of the visual characteristics of the natural landscape in the plant surroundings is of great importance. Accordingly, the following principles were implemented in the planning of the Facility with regard to landscaping and visual aesthetics:

- Minimizing impacts on the natural landscape, as much as possible;
- Merging the appearance of buildings with the local landscape;

- Preserving the natural character of the surrounding landscape;
- Rehabilitation of external areas that might be affected by construction works (e.g. grounds used as temporary organization areas and excess roads) including restoration of the original topography, as much as possible.

The detailed planning involved relevant experts such as a landscape architect, agronomy consultant, etc. Specifically, the following elements were implemented:

- Water retaining buildings are constructed with smooth concrete surfaces.
- Buildings are constructed with the facades based on a combination of steel frames and concrete sheet templates, and roofs of insulated panels. The concrete sheet templates are painted in colors that lend the buildings an appearance that blends with the natural view of the local environment.
- The maximal height of all plant structures is according to local/regional regulations.
- Trees and bushes are planted around and between the buildings to create a strip that conceals the buildings and blends them with the landscape.

#### 3.4. Environmental monitoring

After commencement of plant operation, a routine environmental monitoring program will be put in place in accordance with relevant statutory requirements (e.g. the permit for marine discharge of the concentrate). The program includes both in-plant monitoring of the intake water and the concentrate streams and marine environmental monitoring (seawater, sediments and biota). The monitoring program is designed based on the characteristics of the concentrate and the receiving environment, and takes into account the results of the Marine Dispersion Model and the background Marine Monitoring Survey.

The results of the monitoring will be used to verify the impact assessments associated with the operation of the plant and to trigger additional mitigation measures, if necessary.

## IV. FIELD EXPERIENCE [4]

Among the potential adverse environmental impacts of SWRO plants described in the previous sections, the focal point for concern are the potential impacts on marine ecosystems due to concentrate disposal. While it is widely suggested that SWRO concentrates have strong potential to have negative impacts on the marine environment, much of the discussion around this issue is speculative in nature and not based on actual monitoring of SWRO operations. Especially lacking are results of systematic monitoring of concentrate discharges from large SWRO plants.

In Israel, three SWRO plants along the Mediterranean coast at Ashkelon, Palmahim and Hadera, currently produce nearly 300 million m<sup>3</sup>/year (Mm<sup>3</sup>/y) of fresh water, equivalent to approximately 20% of the country's total potable water resources. Currently, the Hadera and Ashkelon plants are among the world's largest operating SWRO plants. In mid-2013, the larger Sorek SWRO plant, now under

construction, will add 150 Mm<sup>3</sup>/y of fresh water, and with the construction of two additional facilities it is expected that by the end of 2013 SWRO will supply 600 Mm<sup>3</sup>/y.

The Israeli regulatory framework for desalination plants requires baseline, as well as operational, environmental monitoring related to disposal of the concentrates. Monitoring programs aimed at assessing the environmental impacts of the concentrates of the Ashkelon, Palmahim and Hadera desalination plants were implemented shortly after the commissioning stage of each plant, and Sorek's plant monitoring program will be implemented this spring, after approval by the regulatory bodies.

The extensive chemical and biological monitoring related to disposal of the concentrates of the Ashkelon, Palmahim and Hadera SWRO plants provides a wealth of data for scientific assessment of actual environmental impacts and their spatial extent. This data was examined with respect to a series of focused questions covering a broad range of potential environmental responses, from effects on water column processes and sediment quality to effects on benthic organisms.

The phytoplankton biomass has not changed significantly in any of the areas as a result of the SWRO concentrate discharges, and the discharges certainly did not cause any algal blooms or proliferation of toxic algae. The levels of heavy metals recorded in the water column in the three areas are much lower than water quality criteria for the protection of marine life and, therefore, do not represent a risk to marine organisms. Likewise, the levels of heavy metals recorded in the sediments are lower than concentrations considered harmful and, therefore, do not represent a risk to benthic organisms. Coagulant materials do not accumulate in the sediments and thus there is no risk of smothering of sessile organisms or of ingestion of foreign materials by filter and sediment feeders. Currently, none of the concentrate discharges constitutes an aesthetic problem. The only negative "environmental response" that can be attributed to the SWRO concentrates on the basis of the monitoring results, or to the combined discharges of the concentrates and power plant cooling water at Ashkelon and Hadera, is changes in the benthic infaunal communities. However, the changes observed are confined to very small areas (less than 0.2 Km<sup>2</sup>) near the outfalls and it is highly unlikely that such changes have significant ecosystem impacts.

The overall conclusion that can be reached from the monitoring results is that the concentrates of the Ashkelon, Hadera and Palmahim SWRO plants do not have significant adverse impacts on the ecosystems of the receiving environments. Thus, to date, the Israeli experience demonstrates that with proper selection of discharge methods and sites, concentrate discharges from large SWRO plants can be environmentally safe. A similar conclusion has also been observed for the Australian Gold Coast Seawater Desalination Plant, where results of various monitoring programs indicate minimal impact on the marine environment [5].

## V. NEW APPROACHES

The primary directions in which desalination solutions can demonstrate environmental responsibility is through the elimination of the need for chemicals, and therefore for the safe disposal of spent chemicals;

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<sup>7</sup> The equivalent diameter (D) is:  $D = 2 * \sqrt{A/n}$ , where A is the area where the water salinity exceeds the ambient by a specified percent.

lowering energy consumption to reduce the CO<sub>2</sub> footprint; and minimizing disruption to the landscape and seascape in the vicinity of the plant.

### 5.1 Chemical Free Desalination and Lower Energy Consumption

One of the primary uses of chemicals is in the pretreatment process. Typically, pretreatment of raw seawater uses chemicals such as chlorine, sodium bisulphite, coagulants and flocculants. Today more resources are being invested in the development of alternate methods of pretreatment including, but not limited to, methods such as chemical-free, contact flocculation and multimedia gravity filtration processes. The challenge facing developers is to have these methods able to remove fine suspended solids and dissolved organic contaminants from the feed water, delivering treated water with a Silt Density Index (SDI) that complies with the guidelines established by membrane manufacturers for the safe operation of RO systems.

The chemical-free concept can also be extended to the reverse osmosis (RO) process itself, utilizing various methods of cleaning that are not based on the use of chemicals. One example of such a method is the patented Direct Osmosis Cleaning (DOC) process. The concept for the DOC process is to clean the membranes with pressurized permeate water, a process that requires no plant stoppage, enabling stable performance and high quality water production even during the cleaning process. This is in sharp contrast to chemical membrane cleaning processes, which require the shut-down of plant operations for up to 24 hours at a time, disrupting plant operations and reducing plant availability significantly. Furthermore, it is expected that the flux of conventional membranes will decrease annually by 7-10%, requiring higher use of energy to achieve the same level of production.

### 5.2 Pressure Center Concept – Lower Energy Consumption

One of the keys to increasing the efficiency of a desalination plant is to increase its operating flexibility, enabling the adjustment of production rates in response to dynamic changes in demand and water quality. To this end, IDE's mega desalination plants have implemented a unique Three Pressure Center design, which separates the operation of the RO membrane segment from the traditional pump – membrane rack – energy recovery multi-train concept. The feed pumping center itself includes High Pressure (HP) pumping and Energy Recovery System (ERS) pressure centers. The HP pumping center supplies the HP feed to the RO banks via common feed lines, and can be optimized by the selection of a minimal number of large HP pumps working at the highest efficiency rates and best operational conditions. This model has demonstrated its ability to increase availability and reliability, to deliver higher efficiencies and flexibility under variable operational modes, to lower the overall energy consumption and to lower overall CAPEX/OPEX costs.

### 5.3 Optimization of Membrane Size and Configuration – reduction in plant footprint

A key contributor to the efficiency of IDE's mega-sized plants is the optimized configuration of the RO membrane banks. Utilizing a patent-pending design, IDE's Ashkelon, Hadera and Sorek plants have implemented a minimal number of independent trains fed by both feed pumping centers. In Sorek, this design has been enhanced by the implementation of 16" membrane elements installed in vertical pressure vessels. The behavior of the 16" membrane element, as complemented and confirmed by the installation and successful continuous operation of vertical 16" pressure vessels in IDE's Larnaca and Hadera Plants, is identical to that of the 8" membranes typically used in SWRO plants, resulting in

identical salt rejection performance and a correspondingly 4.3 times larger flow rate at the same feed pressure and operation conditions.

The combination of the proven 16” membrane technology installed in vertical pressure vessels results in an optimized design that enables significantly reduced membrane handling in maintenance operations. This approach allows a significant reduction in plant footprint, shorter and smaller diameter HP pipes and an improved membrane loading method. In addition, due to the larger volumes of feed water, this design reduces membrane fouling and polarization.

## **VI. CONCLUSIONS**

Most of the potential environmental impacts during construction and operation of desalination facilities are of a local nature, i.e., of localized spatial extent. The potential environmental impacts during operation are mostly continuous, while those associated with construction activities are temporary and mostly reversible.

Specific mitigation measures are presently available and they represent the ‘best available technologies’ with respect to environmental management of desalination facilities, ensuring compliance with the requirements of the applicable environmental legislation relating to environmental aspects.

Results of various monitoring programs in Israel and Australia clearly indicate minimal impact on the marine environment resulting from the operation of large scale desalination facilities.

## **VII. REFERENCES**

1. The US EPA National Recommended Water Quality Criteria for Marine Waters (2006)
2. The Australian Water Quality Guidelines for Marine Waters (2000 as amended)
3. The Recommended Marine Water Quality Standards for the Mediterranean of the Marine and Coastal Division of the Israeli Ministry of Environmental Protection (2002).
4. Seawater Desalination and the Environment - the Israeli Experience, Prof. Yuval Cohen, Israel Desalination Society, 12th Annual Conference, Dec. 2011, Haifa
5. Impacts of Desalination on the Marine Environment – Some Significant Benefits. Gordon, H.F. et al., IDA World Congress 2011, Perth, Australia