IDS-Water - **White Paper**

Title:	Minimizing the Impact of the Desalination Processes on the Environment
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1. Introduction

According to the Bible, the first project of desalination was conducted by Moses at the place of Mei Mara in the Sinai desert, where by introducing a piece of bitter wood into the bitter water Moses has turned the previously bitter fluid into potable water. The first scientific report describing a technology designed for the desalination of seawater was published by Thomas Jefferson, the American Secretary of State, in 1791 [1]. Instructions for operation of the technology were posted on notice boards in every ship, for use in a case of emergency. During the Second World War, hundreds of portable desalination devices were used by the troops of the various armies. In the early fifties, research projects were initiated with the aim of lowering the price of the desalination process. The incorporation of membrane processes resulted in a major improvement to the technique. The increase in the standard of living in the developing countries during the second half of the 20th century resulted in an increased demand for water for daily use as well as for industrial use. At the same time, clear water, regarded in the past as a natural resource, available and cheap, had turned into a precious commodity. A number of reasons may be given to explain this process: growth of the population, wasteful use of water, pollution of available water resources, and climatic changes related to global warming. At the beginning of the third millennium, we are facing a revolution in the desalination process, where reasonable costs and a continuous trend of further lowering the costs, will enable the supply of water of high quality at convenient prices, thus allowing expansion of residential areas as well as an improvement in the quality of life of people all over the world.

The yearly deficit in Israel's water budget, as estimated in 2001, is between 200 and 500 million m^3/y. A desalination plant, such as the one to be constructed in Ashkelon, would be capable of producing 100 million m^3/y of water (320,000 m^3/d), accounting for 20–50% of this deficit. Being the first in a line of plants to be constructed places great responsibility on the planners and on those who approve the plans, to establish proper standards that can meet with environmental demands. The construction of plants for seawater desalination is the preferred environmental option for reducing the water budget deficit, but first the environmental price of such plants should be thoroughly researched and taken into account.

The common technologies for seawater desalination are based on two main processes — evaporation and membrane separation, as shown in Table 1 [2–4]. In general, all processes of evaporation require large amounts of energy and therefore are suitable only to areas that are rich in cheap fuel. The cost of energy is the main production expense in desalination plants (excluding the amortization) and the process of reserve osmosis (RO) is the most efficient desalination process both in terms of energy and costs [5,6]. For this and other reasons reverse osmosis is becoming the established and preferred desalination process all over the world and in particular in Israel, and therefore most of this paper will be dedicated to it.

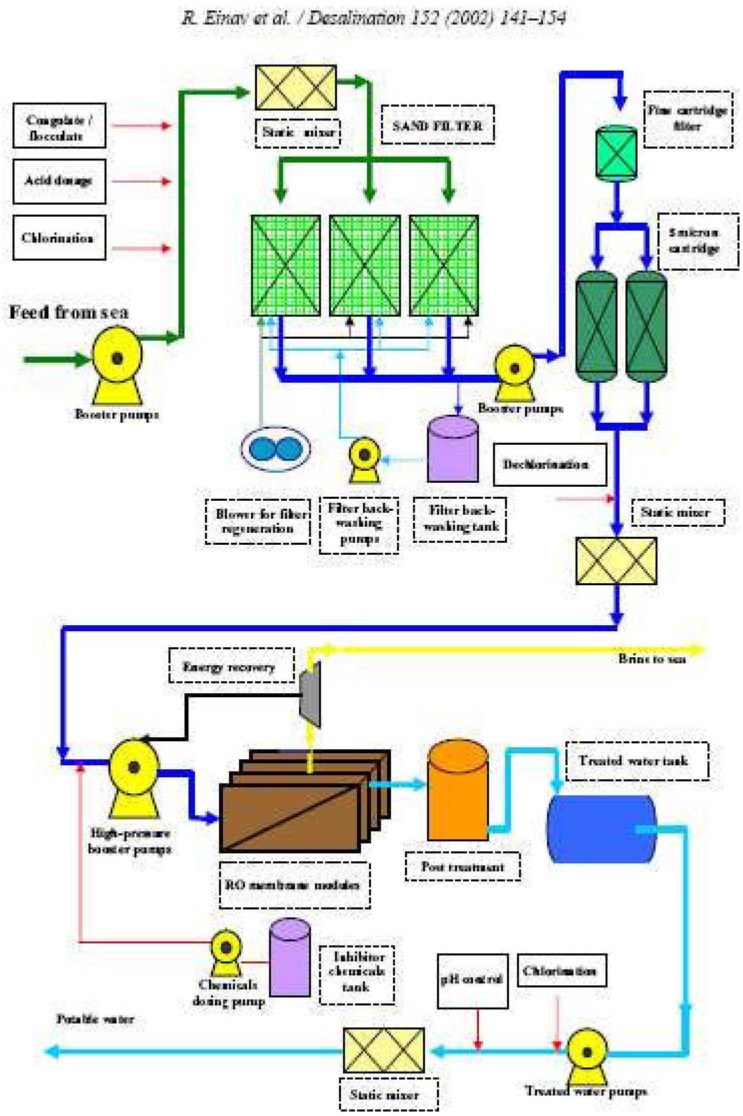
Table 1. Common desalination technologies [2,3]

Reverse osmosis (RO)	Membrane processes, the most common system in use. A semi-penetrable membrane separates two solutions of different concentrations.
Electrodialysis (ED/EDR)	Membrane processes. A bundle of membranes is placed between two electrodes and an electric field is induced. It is mostly suitable for brackish water and for the remediation of polluted wells.

Multi stage flash (MSF)	Evaporation processes, in combination with power stations. The system includes a series of compartments. The flow of hot water into a compartment in which there is low pressure results in the evaporation of part of the water.
Multi effect distillation (MED)	Evaporation processes, based on the cycle of latent heat when generating steam, usually used in combination with power stations.
Vapor compression distillation (VCD)	Evaporation processes based on the principle of a heat pump. Repeated cycles of condensation and evaporation.

The process of reverse osmosis is based on the fact that in all salt solutions an osmotic pressure arises whose magni cxctude is proportional to the salt concentration. When a semi-permeable membrane is placed between two solutions of different concentrations and osmotic pressures, the difference in osmotic pressures will result in a flow of solvent (and a tiny part of the solute) through the membrane, from the less concentrated solution to the more concentrated one. In the process of reverse osmosis, the direction of the solvent flow is reversed by exerting external pressure, higher than the difference in osmotic pressures, on the more concentrated solution.

A reverse osmosis plant consists of a bundle of membranes placed in a pressure chamber, a high pressure pump, a turbine for recovering energy from the high concentration brine which is discharged from the plant, and a system for the pretreatment of the feed water and the product water. In this process (see Fig. 1), the seawater enters a pretreatment system, which contains sand filters, micron filters and a system for chemical dosing. The purpose of this pretreatment system is to protect the membranes from fouling by dirt, biological or chemical deposits. The feed pump generates seawater flow at pressures of 55– 80 atm. through the membrane system. The desalinated product water, which has passed through the membranes, then receives a final treatment, which includes the adjustment of its reactivity ratio, the reduction of its corrosivity and its disinfection. The discharged brine passes through the turbine, which recovers 30–40% of the energy invested by the process pump and is then returned to the sea. A secondary system used for periodical cleaning of the membranes is installed in each reverse osmosis plant.



There are five aspects to the impact of desalination plants on the environment:

1. Adverse effect on land use. As factories are located near the shoreline, seashores serve as the sites for industrial plants and for pumping stations rather than for recreation and tourism.
2. Impact on the aquifer. If a desalination plant is constructed inland in order to minimize the impact on the beach, there is a need for pipes to transport the seawater and brine. Leakage from the pipes may result in penetration of salt water and therefore presents a danger to the aquifer. The aquifer is further endangered if drilling is initiated in order to draw brackish feed water.
3. Impact on the marine environment as a result of returning the concentrated brine to the sea. Although the brine contains materials, which originated in the sea, its high specific weight and the potential presence of additional chemicals introduced in the pretreatment stage may harm the marine population in the area of the discharge of the brine. The installation of the feed and discharge pipes may itself be harmful. Layers of sand and clay may suffer re-suspension during the laying of the pipes and rocky areas and reefs may suffer mechanical blows.
4. Impact of noise. Seawater desalination plants require the use of high-pressure pumps and turbines for recovering energy, which produces noise. They should therefore be located far away from populated areas or equipped with the appropriate technologies for lowering noise intensities.
5. Intensive use of energy. This has an indirect impact on the environment due to the need to increase production of electricity with the wellknown related environmental consequences.

2. The use of land

The environmental value placed on the use of land changes from place to place and is dependent on the population density and on the public awareness. In many places this value is negligible, but in places with limited seashores, such as the State of Israel, there is a high value attached to each strip of shoreline, which could be used for internal tourism, external tourism and for conservation of nature. The area required for a seawater desalination plant (including pumps and holding ponds) is about 25 acres for a plant that produces 100 million m^3/y. In an area smaller than a 1000 dunams it is possible to desalinate 1 billion m^3 of water.

The outline scheme for the development of the coasts of Israel designate limited areas only for heavy industry, no building is allowed within 100 m from the shoreline (with a few exceptions).

One of the solutions for minimizing the use of coastal land when building desalination plants is locating the plants farther inland. This introduces the problem of using pipes for transporting large amounts of seawater and brine, with the danger of pollution to the underlying aquifer from potential leakage. Placing the desalination plant adjacent to areas with established and operating infrastructure, in the framework of infrastructure unification, will minimize this impact.

3. Impact on groundwater

Pipes of seawater laid over the aquifer pose a danger to it as these pipes may leak and salt water may penetrate the aquifer. The coastal aquifer of Israel extends to most areas along its Mediterranean shores and thus lies under most of the potential sites for an inland desalination plant. As a result, the laying of pipes carrying seawater and brine necessitates the use of proper sealing techniques and the installation of detectors, which would stop the pumping in case of a malfunction. The preferred site for a plant is an area where the probability of harm to the aquifer is low.

The supply of feed water from feed drilling is a reliable technology. Its main advantage lies in the provision of clean and filtered seawater, the significant reduction in the danger of pollution, and the stable temperature of the feed water. The use of water from feed drilling also allows for savings in the pretreatment stage. The drawbacks of the system are the danger of disturbing the water table and the aquifer. In many cases (for instance in the plant in Ashkelon) this option was ruled out in advance.

4. Impact on the marine environment

Most of the impact on the marine environment is a consequence of the positioning of the feed pipes and the brine discharge pipes. The initial impact during the laying of the pipes is temporary and confined to the location of the works, but even this impact may be significant, especially in rocky habitats and coral reefs. The severity of the impact is a function of the level of disturbance to the environment and of the natural sensitivity, which in turn is dependent on the specific nature of the habitat and on the specific communities.

The main impact is due to the discharge of the concentrated brine to the sea, and its magnitude depends on environmental and hydro geological factors characteristic of the sea: bathymetry, waves, currents, depth of the water column etc. These factors would determine the extent of the mixing of the brines and therefore the geographical range of the impact.

Höpner and Windelberg divide the global marine habitats into 15 categories according to their sensitivities to the effects of desalination plants [7] (Table 2). According to the hierarchy, which they suggest, the sites most suitable for the construction of desalination plants are the shores of the ocean (No. 1), in regions of high-energy oceanic coasts. The most sensitive regions (No. 15) are Mangal, mangrove flats. Because of the diversity of species characteristic to them, coral reefs are rated at 13.

4.1. Composition of discharge brines

In all processes of desalination, discharged brines, the concentration of which is higher than that of the natural seawater, are returned to the sea. The concentrations of the brines are usually found to be double or close to double that of natural seawater [8]. In addition to the high concentration of salts, this discharge water contains various chemicals used in the pretreatment stage of the desalination, including various defouling materials. In the case of evaporation plants, thermal pollution is also produced.

Table 2. Sensitivities of marine habitats to desalination plants [7]

1.	High-energy oceanic coasts, rocky or sandy, with coast-parallel current
2.	Exposed rocky coast
3.	Mature shoreline (sediment mobility)
4.	Coastal upwelling
5.	High-energy soft tidal coast
6.	Estuaries and estuary-similar
7.	Low energy sand-, mud- and beach rocks-flats
8.	Coastal sabkhas
9.	Fjords
10.	Shallow low-energy bay and semi-enclosed lagoon
11.	Algal (cyanobacterial) mats
12.	Seaweed bay and shallows
13.	Coral reefs
14.	Salt marsh
15.	Mangal (mangrove flats)

The types and the amounts of the chemicals used depend on the chosen technology and the required quality of the product water. Chemicals that are likely to be found in the brines include antiscaling materials, surfactants, and acids used for the lowering of pH. The salts returned to the sea are identical to those present in the feed water, but they are now present at a higher concentration. In plants of reverse osmosis, the discharge concentration is 30–70%, or 1.3–1.7 times that of the original seawater. This is a higher concentration than the one found for MSF plants where the return ratio is 1.1–1.5 [9–11].

The chemicals used in the pretreatment of seawater are mainly [12,13]:

- NaOCl or free chlorine, used for chlorination, preventing biological growth (antifouling).
- $FeCl_3$ or $AlCl_3$, used for the flocculation and removal of suspended matter from the water.
- $H2SO_4$ or HCl, used for pH adjustment.
- SHMP $(NaPO_3)_6$ and similar materials, prevent scale formation on the pipes and on the membranes.
- $NaHSO_3$, used in order to neutralize any remains of chlorine in the feed water.

All these materials (in concentrations and amounts which are similar to those used in desalination plants) are approved for use by the American EPA and most of them are used in systems for drinking water. Chemicals that dissolve in seawater may contribute ions identical to the ions already present in the seawater. For instance, sulfuric acid increases the concentration of the SO_4 ion from 3020 to 3050 mg/l, an increase of about 1% above the natural concentration of seawater (based on technical information from the Hydranautics company and its rodesign simulation package). Cleaning of the membranes is conducted 3 or 4 times a year, and the chemicals used are mainly weak acids and detergents (citric acid, sodium polyphosphate and EDTA which is used in order to remove carbonate deposits). The rinse water is kept in a titration container and after being treated (titration, neutralization of the cleaning materials), it is disposed off either by transporting it in closed containers to an authorized salt disposal site, or by the continuous flow of small quantities together with the discharged brine back to the sea. The high dilution ratio (about fifty to one million) ensures very low concentration of rinsing materials in the brine returned to the sea. Tables 3–5 show some estimates regarding the materials, which would be returned to the sea in the planned desalination plant in Ashkelon [12].

4.2. Dispersion of the concentrated salts

The major environmental problem associated with a desalination plant is how to get rid of the surplus of concentrated brines. In most cases, these brines cannot remain on land because of the danger they pose to the underlying groundwater and because of other potential and severe environmental impacts. A natural disposal site for these brines is the sea, but an appropriate technology is required in order to insure the proper dispersion of the concentrated solutions and thus minimize their adverse effects on the marine environment. Several alternative techniques are available for this purpose, and the choice between them would depend on the particular conditions in the area, taking into consideration the environmental, engineering and economical aspects. The alternative techniques are:

- Discharging the brines by a long pipe far into the sea.
- Direct discharge of the brines at the coastline.
- Discharging the brines via the outlet of the power station’s cooling water
- Directing the brines to a salt production plant.

Table 3. Flows of seawater and brine

	Feed — seawater	**Discharge brine returned to the sea (including rinse water)**
Hourly flow, m^3	13,000	6,750
Concentration of salts, mg/l	40,500	77,920
Total amount of salt, t/h	526	526

Table 4. List of chemicals and the amounts used in the pretreatment stage

Chemicals	**Doses, mg/**	**Flow, kg/h**	**Daily amount, t**	**Accumulated volume (diluted material), m^3**
Sodium hypochlorite	6	80	1.9	120
Sulfuric acid 98%	30	390	9.4	100
SHMP (scale remover)	6	80	1.9	120
Iron chloride — flocculant to treat suspended colloids	4	50	1.2	120
Sodium bisulphate	4	50	1.2	120

Table 5. Cleaning and rinsing of the membranes

	Yearly amount, t	Storage volume, m^3
Citric acid	70	30
Sodium tripolyphosphate	50	20
EDTA	30	10

4.3. Discharging the brines by a long pipe far into the sea

The brines, which would be routinely returned to the sea, would form a plume of highly saline seawater, corresponding to their amount and to the conditions of the sea (depth, bathymetry, currents, etc.).The plume would sink to the sea floor and its effects would extend over a range of hundreds of meters.

As this presents a continuous and cumulative source of pollution, it would result in a continuous damage to the biota within the plume's vicinity. It is therefore desirable to place the point of brine discharge far away from the beach and from rocky areas which are rich in organisms, as well as far away from areas where large numbers of people are involved in activities such as recreation, touring, fishing etc.

Most of the data in the literature and most of the practical experience regarding the flow of liquids into the sea is related to various forms of sewage discharge, where the effluents float on the seawater because of their lower densities. These forces of buoyancy are important in the dilution process of water jets [14] but do not exist in the case of concentrated brine discharge. The process of brine dilution is a combination of two physical processes: the primary (jet) dilution and the natural dilution.

The rate of the jet dilution process depends on the difference in densities (a function of the concentration of salts and of the temperature) between the concentrated brine and the seawater, as well as on the momentum, the rate of the flow and the velocity at the outlet of the discharge pipe. The jet dilution is further affected by the diameter of the discharge pipe and by the depth of the sea floor. In the case of brine, the water jet descends to the bottom and the effectiveness of this stage is reduced. Appropriate planning of the discharge pipe, such as the incorporation of diffusers directed upwards, may improve the jet dilution process [15,16].

The second phase is the natural dilution (turbulent dilution), which takes place following the jet dilution stage, mainly as a result of processes of diffusion and mixing which are generated by marine currents and waves. It varies according to the marine conditions.

Installation of diffusers on the discharge pipe boosts the turbulent dilution. The diffusers enable the increase in the pressure of the entering solutions and increase the volume of seawater in contact with the brine, therefore improving the mixing. The success of the diffusers operation depends on their number and on the space between them. It is possible to improve the dispersion efficiency by using special diffusers, such as Red Valve diffusers. These boost the brine pressure at the outlet of the discharge pipe and thereby improve the dilution. Another option is the use of diffusers directed at an angle of 30–90° to the sea floor, so that the concentrated brine is pushed in the direction of the surface of the sea.

The main effects on the marine biota would be in the vicinity of the discharge pipe and would be related to the increase in the concentration of salt. This would mostly affect benthic organisms dug in the sandy bottom as well as planctonic organisms. The salinity is expressed in weight of salts per l‰ and in most seas and oceans its value varies between 32–38‰, which is the range to which most marine creatures have adapted. The eastern part of the Mediterranean is more saline that its western part [17]. In the Red Sea salinities may reach a value of 41‰.

Marine organisms exist in an osmotic balance with their environment and an increase in the concentration of salts in this environment may result in the dehydration of cells, decrease of the turgor pressure and death (mainly of the larvae and young individuals). The biomass in Israel's Mediterranean coasts is composed of species, which have originated from Pacific and Atlantic species. The Atlantic species, found in the Eastern Mediterranean, are at the limit of their tolerance to the water salinity, while species that have originated in the Pacific can cope more easily with an increase in salinity.

The sensitivity to the increase in salinity varies from species to species. To the best of our knowledge, no systematic research has yet been conducted on the tolerance of the various species in our region to variations in salinity. Some of the planktonic algae, and in particular the siliceous ones, can tolerate high salinities (these species appear in coastal salt marshes, such as the Bardawill), but most of the species will not survive. Certain species are able to tolerate higher salinities after a period of acclimatization, but the nature of the discharge flow would not enable the foundation of a population of halophile species at the outlet of the discharge pipe.

The sensitivity of the invertebrates, mainly that of crabs, varies but in general it is found that long abdomen invertebrates are more sensitive to an increase in salinity than short abdomen ones. The larvae of crabs and of other invertebrates, which float in the water, are more sensitive than the adults to changes in salinity [18–21].

Data from systematic monitoring of the dispersion of concentrated brines in marine outlets is scarce, and the only information we have available is from Cyprus and the Canary Islands. Two desalination plants operate in Cyprus: the plant in Dhkelia, which has operated for 4 years and the new plant in Larnaca, which has operated for a few months only [7,22].

4.3.1. The plant in Dhkelia

The length of the discharge pipe is only 250 m. The suction feed pipe is only 200 m away from the outlet of the discharge pipe and extends 150 m into the sea. The Cyprus Department of Fisheries monitors the site. An increase in salinity within a range of 100–200 m from the outlet of the discharge pipe has been reported [23–26]. In a dive performed on March 7, 1999, around the area of the outlet of the discharge pipe, an impact to the life of the littoral fauna and the flora was observed, as witnessed by the disappearance of certain species from the littoral due to the increased salination in that area.

4.3.2. The plant in Larnaca

The plant in Larnaca was built by the IDE and Oceana companies. At present it is owned by IDE, which will remain the owner for the next 10 years, at which point the ownership will be transferred to the government of Cyprus. The plant was completed a few months prior to the writing of this paper. It is intended to produce 54,000 m^3 of water daily and a similar amount of brine. Following the experience in Dhkelia, the Cyprus Department of Fisheries demanded that a discharge pipe of 1 km length at least would be provided, with its outlet at a depth of more than 10 m below sea surface. The existing pipe is 1500 m long and is located 25 m below the surface. The suction feed pipe is 1100 m long and is located more than 2 km away. According to Marina Argiro (Cyprus Department of Fisheries), the first measurements conducted in the site point to good dilution conditions.

An impressive study carried out in the Canary Islands was presented in a conference that took place on the 28–31 of May 2001 in Cyprus. The work included both a survey and the monitoring of the dispersion of concentrated brines past the outlet of the discharge pipe, and the influence on the marine flora [27]. The research was carried out at the plant of Maspalomas II. The plant produces about 17,000 m^3/d (about 10% of the amount expected in the plant of Ashkelon). The discharge pipe is 300 m long, its diameter is 60 cm and the water depth is 7.5 m. It should be noted that the topographic structure of the sea floor in the area is characterized by a shallow shelf extending out a few meters followed by a steep fall off. The sea in the region of the island is often rough, and the tide rises about 2 m. The measurements were conducted by divers under calm conditions of the sea. Even though dilution was satisfactory at the surface of the sea, sinking of concentrated and dense solutions to the bottom was still observed. In measurements that were conducted later in the region of the plume, a concentration of more than 60‰ was detected at a distance of 100 m from the outlet, and as a result other regions within the plume are to be monitored. The plume took an elongated form, resembling a salty underwater river flowing in the direction of the fall line. Impacts on the local marine flora in the vicinity of the outlet were observed.

4.4. Direct discharge of the brines at the coastline

The alternative of discharging concentrated salt solutions directly at the coastline is not recommended by the authors of this paper, although under certain conditions (small plants, insensitive shore) it should be given some consideration because of economical factors. Brine water, which is continuously returned to the sea, will form a plume of high salinity seawater, depending on the marine conditions and other factors. The effect will be noticeable at distances of hundreds of meters from the outlet (depending on the amounts of the brines). Even if the brines would be mostly diluted at a short distance from the outlet, during the many days in which the sea is calm (such as during easterly winds), the secondary dilution would be negligible. On those days the damage to the coastal habitats would be high. This method is not recommended for seas with high sensitivity, or for large desalination plants, or for areas with population of high environmental awareness.

In Malta there is a desalination plant that has been operating for many years. The plant discharges the concentrated brines directly into the sea, but dilution with seawater is fast due to the great depth (27–30 m). To the best of our knowledge, no environmental survey was conducted in the region (personal information, Domovic Darko).

In Saudi Arabia there are several large-scale desalination plants in operation (quoted as producing one billion m^3/d) but the general environmental awareness in the country is very low. The concentrated brines are discharged directly into the sea and contain chemicals from the pretreatment stage as well as membrane cleaning materials. The brines are carried away by the tide and by the marine currents. We estimate that the depth of the sea is greater than that of the Mediterranean, and therefore the dilution is faster (personal information, Nicos P. Isaias and Gerhard L. Schanz).

In Kuwait there are a number of large and energy costly desalination plants that are based mostly on the evaporation processes and are combined with power stations. The concentration of brines at the outlet is lower than the discharge concentrations in plants of reverse osmosis. There is now a tendency there to change to RO plants. The country lacks general environmental awareness and the concentrated brines are discharged into the sea [28].

In Qatar there is a number of large desalination plants in operation, utilizing both reverse osmosis and evaporation technologies (MSF). Large amounts of brine are generated and there is also an associated increase in temperature, but the concentration of salts is relatively low. There is a general lack of awareness as to the environmental effects of the brines. In an essay describing the environmental effects of the plant [9], the marine inlets and outlets are described. The outlets are located near the coastline, and therefore in order to enlarge the plant it became necessary to build a 2 km long feed suction pipe for phase B of the plant.

An interdisciplinary study was conducted in Florida, USA, aimed at checking the effects of the discharge of concentrated brines (and sometimes of hot water) from various outlets [29,30] on the environment. The plants which were studied were small scale ones, the largest plant producing 5500 m^3/d and most of the other plants produced much less. The highest salinity of brine measured was 39 ppt as compared with a background salinity of 35 ppt. The tide in the area varies between values of 1–1.5 m. In most instances the concentrated brines were discharged directly into the sea, but in some cases discharge was accomplished using a short discharge pipe. The population of invertebrates (foraminifera), fish and seaweeds were monitored and so were the salinities along cross sections of 10 m length (in varying directions), both along the sea floor and at sea level. There was no preliminary inspection of the study area and no comparison with a control population. According to the researchers, no significant changes were noted in communities of biota along the sections. Higher concentrations of salt were found in the direction of flow.

4.5. Discharging the brines via the outlet of the power station's cooling water

This option suggests using the hot water discharged from the power station for the dilution of the concentrated brines. The main environmental advantage is the high dilution ratio achieved. An additional advantage lies in the relatively low specific weight of the hot water, which would partially offset the high specific weight of the brines and would therefore reduce their tendency to sink to the bottom.

The combination of a power station and a desalination plant holds many advantages, though most of these are relevant to plants that are based on the various evaporation systems and not to reverse osmosis plants [6,28, 31–33].

Calculations made in Ashkelon and Hadera indicate that the total salinity of the water at the vicinity of the outlet of the discharge pipe would increase by 1 to 5%. According to the available models for dispersion [34,35], the effect of the added brine will disappear at a distance of a few meters from the outlet. In terms of environmental considerations, the preferred mode of operation using this alternative would be to use the existing outlet and monitoring system of the cooling water of the Electricity Company so as to avoid an added impact to the marine environment.

4.6. Directing the concentrated brines to a salt production plant

This option, whereby the salts pumped from the sea are utilized for salt production rather than returned to the sea, presents many environmental and economical advantages. Its only drawback is the small number of salt producing plants found in the vicinity of desalination plants. If using this technology, there would be an advantage to the additional reprocessing of the brines through the membranes, thereby increasing the salinity of the discharged water.

This option is partially employed in Eilat. The Mekorot plant in Eilat (which in the past was based on the Zarchin system) is based nowadays on reverse osmosis and produces almost 12 million m^3 of desalinated water each year. Part of the feed water is brackish water from drilled wells (9 million m^3 in concentrations of 3500–6000 mg chlorides per l) and the rest of the feed is seawater. The concentration of the brines generated from the brackish water is 70% and the brines generated from seawater reach a concentration of 50%. The brines exit the plant at concentrations that are 2.0– 2.5 times higher than the concentration of seawater. The brines are then transferred from the plant to the Salt Company ponds and any surplus (the amount of which varies with the varying seasons), is transferred to the Eilat bird watching center. At the grounds of the center the brines are combined with brines from other sources (the fish growing farms, seaweed growing plant), and are then transferred in an open canal to the sea. As the canal passes through an area, which is a highly saline marsh, and as the flow is by a strong current, it seems that there is no penetration of brine water into the groundwater. The canal's outlet is located in the northern beach area and to the best of our knowledge the rate at which the brine disperses in the sea has not been monitored (personal information, Rafi Iphargan).

5. Noise pollution

A seawater desalination reverse osmosis plant is a noisy plant. Most of the noise is produced by the high-pressure pumps and by the turbines used for energy restoration [36,37]. The impact of the noise does not allow for the operation of a large desalination plant in the vicinity of a population center without the use of technological means. Means for decreasing the noise level include the building of canopies over the pumps and the appropriate acoustical planning of the plant.

6. Intensified use of energy

The intensified use of energy by the desalination plant results in indirect environmental impacts, since the energy requirements of the plant increase the production of electricity, the burning of fuels and in turn the boost the process of global warming. The energy required to desalinate a m^3 of water varies from one plant to another and from technology to technology, and the reverse osmosis technology is the most energy efficient.

Based on various publications, it is estimated that the amount of electricity required to produce 1 m^3 of water varies between 3.5–4.5 kWh/m^3. We estimate the optimal value to be 4.5 kWh/m^3. The amount of coal needed to produce one kWh is 353.8 g. The corresponding amount of crude oil (which varies from plant to plant) is approximately 234.9 g for one kWh. (this data provided courtesy of Dr. Michal Perla, Electrical Company). A plant producing 100 million m^3/y water would require an electrical output of 50–60 MW.

7. Conclusions

The processes of desalination as a source for potable water are about to become more widespread. Our duty as citizens and as planners is to be aware of the environmental aspects related to the various processes and in each case to consider the environmental costs as well as the requirements and the financial costs.

In a paper, which deals with the problems caused by processes of desalination, it is also important to address the numerous advantages, both direct and indirect, of adding desalinated water to the existing water system. The main purpose of seawater desalination is to offset present or future deficits in potable water, by producing water of good quality at a reasonable price. However, the amounts and the quality of the produced water highlight several additional environmental advantages. These advantages are dependent on the intended point of use of the desalinated water as well as on the volume and quality ratio between this water and the rest of the water in the water supply system.

The added environmental advantages of the use of desalinated water are:

1. Improvement in quality and sanitation — by adding to the general water supply water that is free of pollutants, carcinogenic materials, organic materials, viruses as well as of offending colors, tastes and scents.
2. Softening of the water — the advantages to the average household from the softening of water include prevention of clogging of water pipes, prevention of scale formation in boilers and kettles, improvements in laundry and dish-washing efficiencies, etc. The advantages to the industry include savings on water softening expenses, economizing the use of anti scaling materials, etc. The softening of water also reduces the need for detergents and this reduced usage would improve the quality of sewage water.
3. Advantages to the agriculture and the environment — the use of treated wastewaters which contain high concentrations of dissolved salts, sodium, chloride and boron, harms agricultural growth and especially harms sensitive crops. This use damages the soil, interferes with proper drainage, causes the accumulation of salts in the substrata, and even damages the underlying groundwater. It has been observed that salination has already damaged the aquifer and a large number of wells have already been shut down. Any damage to the soil, to the crops and to the groundwater brings with it further damage to the environment and to the economy. The Israeli quality requirements of the product water from desalination specify an upper limit of 0.4 mg/l for boron, so that the product water is bound to be low in salinity, and thus the concentrations of chloride and sodium would be 10–100 mg/l. In addition, there is the potential for a decrease in the amount of salts that are now being added to urban sewage due to the softening of industrial and domestic water. Thus desalination is expected to reduce the salinity of treated wastewater, with all the related implications, including the ability to make intensive use of treated wastewater in various agricultural applications and even as potable water. The only way to insure the preservation of natural water systems is by the addition of artificially produced water for domestic and industrial use.

A balanced environmental evaluation of the processes of desalination will take into account the extent to which the population requires the water, the ability to allocate water for agricultural, industrial and nature preservation needs, as well as the need for drinking water.

A balanced environmental evaluation of the processes of desalination will take into account the level of sensitivity of the corresponding environment, both marine and terrestrial, to the environmental impacts of the desalination plant, and the costs of minimizing these impacts.

A balanced environmental evaluation of the desalination processes will take into account the economical and environmental costs of the various technologies for acquiring water, such as (deep) drillings, recycling, use of brackish water, etc. Taking into account the various environmental aspects, there is an apparent advantage to the use of reverse osmosis processes over the use of evaporation processes [9,37–38].

By employing intelligent planning and the appropriate technologies, it is possible to minimize the adverse effects of seawater desalination plants on the environment. The environmental awareness of the planners, the designers, the decision-makers and the public during the early stages of planning and construction, will enable the construction of environmentally friendly plants.

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