Environmental Regulations for discharging Desalination Brine to the Sea and its Possible Impacts

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Introduction

Marine environmental regulations and guidelines relating to construction and operation of desalination plants in the Israeli coastline vicinity are fairly new approach and therefore are dynamic.

The Ministry of Environmental Protection encourage the construction of desalination plants, regarding them as an important national goal, while providing suitable environmental solutions for protecting and preserving the marine and coastal environment from ruin or deterioration.

The marine environmental policy and regulations are based on the Ministry of Environmental Protection requirements (2002), the National Master Plan for desalination of seawater, 34B3 (2004), the precautionary principle and the acquired experience during almost the last two years, since the first and the largest desalination plant in Ashkelon (VID), 100*10^6 m^3/year, has been initially operated.

Background

There are three main types of desalination discharges:


Seawater desalination - Environmental characterization:

a. Concentrated brine having approximately twice the concentration of ambient seawater.
b. Additives: antiscalants (polyphosphates, polymers), coagulants (ferric sulfate, ferric chloride), membrane preservative (Sodium Bi Sulfite).
c. Pretreatment and post-treatment backwash water: concentrated wastes (suspended solids, turbidity, ferric).
d. Cleaning solutions for membranes and pretreatment (organic an inorganic cleaning)

Potential environmental impacts:

- Increase salinity and density, causing stratification due to concentrated brine. Brine is accumulating at the bottom.
- Eutrification due to phosphates enrichment if polyphosphates are used and if organic cleaning solutions are added to the brine;
- Discoloration due to high concentration of ferric, also with high-suspended solids and turbidity, while discharging untreated backwash water.
- Impact on the composition and distribution of biota.

1 Precautionary Principle: When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically.
**Brackish water (BW):** Desalination of brackish water mainly for reducing chloride or Nitrate concentrations - Environmental characterization:

a. Concentrated brine, which has salinity of approximately third to half of seawater ambient.
b. Nitrogen enrichment.
c. Additives: antiscalants (polyphosphates, polymers)

Potential environmental impacts:

- Decrease salinity and density relative to ambient seawater. Effluent is spreading throughout the water column from the bottom to the surface.
- Eutrification due to high nutrients concentrations and high nutrients loads: Nitrogen- due to high recovery rate and the high raw nitrate concentration. Phosphate – in case of polyphosphonates usage. Silica – changes in the algae composition.
- Impact on the biota (composition, distribution etc’).

**Effluent (EF):** Desalination of pretreated municipal or industrial influent mainly for recovery uses (irrigation, production processes) – Not to be discussed in this article because of its preliminary stage regarding the municipal desalination plans and its minor usage as for the industrial influent so far.

**Environmental Legislation**

The policy and environmental requirements described herewith are mainly based on related legislation of four major laws for the planning and the operational phases.

**Planning phase:** According to planning and building legislation (1965) and The Law for the Protection of the Coastal Environment (2004), any planned facilities for seawater/brackish water will be constructed with a solution for the removal of the concentrated desalination discharge.

**Operational phase:** Discharge of brine to the sea is undertaken only according to a valid permit while applying the best available technology (BAT). BAT is related mainly to discharge outfall design (dilution effect, sediment transport etc’) and pretreatment (such as additives, organics or nutrients removal). The permit is a comprehensive part of the plant license (Licensing of Businesses Law, 1968).

The permit is issued under stipulated conditions, by interministerial permits committee for discharge of waste to sea according to the Prevention of Sea Pollution from Land-Based Sources Law, (1988), and its regulations.

The interministerial committee has eight-member representatives from seven different ministries as well as a representative from public environmental organizations.

The permit is given for limited time and its conditions may vary with time, as necessary.

The Marine and Coastal Environment Division in the Ministry of Environmental Protection serves as a professional advisory body to the committee, coordinates its activities and is responsible for inspection and enforcement of permit holders.

**Environmental Requirements and Guidelines**

The environmental requirements for desalination plants are based on the legislation and the environmental policy (2002), and enclosed by.
**Preparation of an environmental document for the protection of the marine and coastal environment.**

The construction of seawater desalination plant will be accompanied by an environmental document, prepared on the basis of the national Master Plan 34B3 (Appendix 1), with the specific guidelines of the Marine and Coastal Environment Division. In case of brackish desalination plants with a new constructed outfall, preparation of an environmental document will be required.

The main issues that need to be considered related to the marine environmental aspects are:

- Marine outfall
- Marine monitoring program
- Discharge composition

**Marine Outfall - Policy and Guidelines for Protection of the Marine and Coastal Environment:**

Following is a list of criteria for planning marine pipelines in general and marine outfall in particular in a manner that protects the marine environment.

**General:**

Marine infrastructure pipelines such as communication, fuel, water (pumping of seawater for desalination) or gas are based usually on master plans that are approved by authorized planning agencies. Environmental considerations are taken into account during the preparation of the master plans. Furthermore, the Law for the Protection of the Coastal Environment came into effect in 2004 and includes instructions and guidelines for damage prevention to the coastal environment.

**Criteria for a Marine Outfall:**

1. A prerequisite for discharge to sea is the installation and operation of best available technologies (BAT).
2. Discharge will be via an outfall deep into the sea. Discharge to the coast will be prohibited, with the exception of cooling water outfalls of power plants.
3. A diffuser for a better dispersion and dilution will terminate the outfall. In case of desalination brine, heavier than seawater, the outfall termination will be at least 2 meters above the seabed for a better dilution.
4. Approval of the outfall pipeline requires background monitoring and implementation of an annual monitoring plan to examine and estimate the impact on the marine environment once discharge is initiated.
5. The length of the pipeline and its specific location will be determined, among others, according to the following criteria:
   - Minimum outfall length will be 300 meters from the coastline (according to the Bathing Sites Arrangement Order – Ministry of Health).
   - Damage to the coastal area will be avoided, as much as possible, by an outfall extending to a water depth of 30 meters or to a distance of one nautical mile (as defined by the law for the Protection of the Coastal Environment, 2004).
   - Sufficient distance will be maintained from declared and proposed marine nature reserves and underwater habitats.
   - Oceanographic characterization (water exchange, bathymetry, currents etc’).
   - Results of a mathematical dispersion model on the impact of the desalination discharge on the marine environment in relation to marine environmental standards.
• Composition of the proposed discharge.
6. Integrated infrastructures – for the outfall or its corridor with other discharges in the nearby area.
7. The entire length of any marine pipeline will be buried using BAT to minimize damage to the coastal area (as defined by the Law for the Protection of the Coastal Environment, 2004) and especially damage during the pipeline constructions. The following aspects have to be taken into account:
• Natural sand movement
• Ecosystems in the coastal environment
• Fishing activities
• Protection of the pipeline from fishing nets
• Prevention of harm from vessels (include marking in accordance with the Safety of Vessels Regulations).
• Safety of bathers and surfers in shallow waters
8. Coastal facilities related to the pipeline (pumping and treatment facilities) will not be established in the coastal area (100 meter strip) unless they are included in an engineering facilities site (existing) or a port, which is closed and built in any case.

The above-mentioned criteria are framework guidelines. Each case is examined individually.

**Monitoring Program**

A monitoring program for the marine environment will be submitted and implemented according to specific guidelines including background monitoring prior to the operation of the facilities.

The background marine monitoring is required as part of the environmental document for the protection of the marine and coastal environment.

The compliance monitoring is required as part of the discharge permit and include marine monitoring as well as inlet water, brine and backwash monitoring.

The marine monitoring program usually includes the following components:
- Water (physical and chemical, biological tests)
- Sediment
- Biota

Submission of an annual report for all monitoring activities includes: An analysis of the results obtained during the monitoring; statistical analysis of the results and a comparative analysis of trends; analysis of data, undertaken with reference to the environmental quality standards (EQS); Discussion, and recommendations.

**Discharge Quality Standards (DQS)**

The discharge composition is mainly a result of the raw water/wastes composition, pretreatment type, additives types and concentration, recovery rate and the operational regime.

Each type of desalination discharge is examined individually and set accordingly.

An example for DQS determined to the Ashkelon seawater desalination plan is given in the following table:
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Maximum Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspended Solids 105°C (TSS)</td>
<td>mg/l</td>
<td>20</td>
</tr>
<tr>
<td>Turbidity</td>
<td>NTU</td>
<td>10</td>
</tr>
<tr>
<td>BOD$_{5}$(total)</td>
<td>mg/l</td>
<td>&lt;1.0</td>
</tr>
<tr>
<td>pH</td>
<td>°C</td>
<td>9.0 &gt; pH &gt; 6.5</td>
</tr>
<tr>
<td>Ferric (temporary)</td>
<td>mg/l</td>
<td>2.0</td>
</tr>
<tr>
<td>Temperature</td>
<td>°C</td>
<td>4 above ambient seawater</td>
</tr>
<tr>
<td>Nitrogen species</td>
<td>mg/l</td>
<td>Not exceed 1.7 times ambient seawater</td>
</tr>
<tr>
<td>NO$_3$-N, NO$_2$-N, NH$_4$-N, TKN, TN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phosphorous species</td>
<td>mg/l</td>
<td></td>
</tr>
<tr>
<td>PO$_4$-P, TP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy metals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ag, Cd, Cu, Cr, Hg, Ni, Pb, Zn</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) Turbidity, TSS, BOD’s maximum concentration at any time, won’t exceed the above concentrations or up to 1.7 times the ambient seawater concentration. 1.7 is a factor based on the mean recovery rate and might change as a result of the plant’s operation regime.

(2) Ferric temporal discharge standards are for daily mean. Future concentrations to be studied and tested are: 0.5 mg/l (max.) and 0.3 mg/l (mean).

**Dispersion Model Results and First In-Situ Observations**

An example for model results to assess the distribution of brine discharge is the CAMERI 3D numerical model applied to the Ashkelon desalination plant (VID). The model simulated several events, and one of them is illustrated herewith.

Model results of salinity spreading at worse case scenario, where no cooling water of the power station, wind or wave exist (Discharge conditions: flow discharge 21,000 m$^3$/h, salinity 73.5 g/l, rate of salt discharge 429 kg/sec (Figure 1).

*Red brine phenomena*

As the first and the largest desalination plant in Ashkelon has been operated since 2005, a phenomena of reddish brine has been observed. This happens almost every hour for 10-20 minutes while untreated backwash water, with high ferric concentration, 40 mg/l and more, about 450 ton/year is discharged with the brine as shown in figure 2.
The discolored plume has been observed at a distance of more than 1 Km from the outfall, as a function of the weather conditions.

As for the salinity dispersion, outfield compliance monitoring results have shown that 1% salinity above ambient water spread for kilometers although the dilution effect of the cooling water (fig 3).

According data reported by Mekorot company, in 2005 the brackish water desalination plant at Ashkelon site discharge $\sim3.5*10^6$ m$^3$/y (product water), 750,000 m$^3$/y (brine), with high concentration of nitrates ($\sim 63$ mg/l as NO3-N, $\sim 50$ ton N/y) and silica (113 mg/l, 115 ton/y).

In 2005 National Monitoring Program report (IOLR), a unique distribution of diatom algae (assimilating Silica) was found at Ashkelon region (some of them have a potential toxicity). It is important to highlight that in the future, higher nutrients concentrations and loads up to three times are expected.

**Summary**

It is important to realize that there is still very little information on the impact of desalination discharge on the marine environment. It is mostly emphasized while dealing with the largest operated desalination plants together with its location in the Mediterranean Sea, having relatively low circulation rate.

For all these reasons, decision makers must take the precautionary principle in their environmental policy, meaning mainly applying BAT for the protection of the marine environment and preventing potential risk.

The main issues regarding precautionary principal in desalination plants as for the environment includes:

- Marine outfall design and constructed for best dilution and for minimizing disturbances to marine environment and to sediment movement;
- Polyphosphates replacement by friendly environment antiscalants and other friendly additives;
- Removal of ferric, not only for the discoloration and aesthetic matter, but also for the preventing of a potential risk for the marine environment due to the high loads and accumulation with time;
In case of brackish water, highly consideration should be taken for pretreatment for nitrogen removal, to prevent nutrient enrichment, eutrophication and decrease in water quality.

Figure 3: Salinity distribution – Ashkelon site (2005 monitoring program (autumn)- IEC).
References


Galil, B (2004). Possible Biotic Impacts of Brine Discharge from the Ashkelon Desalination Plant.


