DISPOSAL AND RECIRCULATION OF SALINE WATER

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Keywords: Advection, Diffusion, Dispersion, Recirculation, Salinity

Contents

Summary

The intake of seawater with the lowest possible salinity and temperature has advantages for its application as raw material for the desalination process and as cooling water for the plant. The discharge of the plant's effluent with excess heat and salinity must take place in such a way that minimum recirculation to the intake takes place, while often ecological issues are also involved.

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The design of a useful and safe offshore intake/outfall configuration requires a good knowledge and modelling of the marine environmental characteristics, e.g., currents, water temperatures, stratification, bathymetry, biological species and ecosystems.

Hydrodynamic modelling is essential in order to investigate the most important features dealing with the effluent discharge: the advection and dilution by and with the ambient flow. The modeling of the following phenomena is described:

- Flow conditions and stratification in the ambient flow;
- Discharge of effluent into and withdrawal of water from the sea;
- Heat exchange between water surface and atmosphere, and solar radiation;
- (The processes dealing with water quality with respect to ecological issues are not discussed in this section.)

A case study is described as an illustration of the actions to take in order to optimize the intake/outfall configuration of a planned combined power and desalination plant.

1. Introduction

1.1. Plant Intake and Discharge of Water

The seawater intake of a desalination plant supplies the raw material for the desalination process and the water for the cooling system. The outfall discharges the highly saline water (brine) from the desalination process and the heated water from the cooling system.

In many cases the desalination plant is located in combination with a power plant on a site at the shoreline, combining the intake and outfall system. The power plant needs the intake and outfall of water for the cooling system.

Clearly, the intake of seawater with the lowest possible temperature has advantages for its application as cooling water for the desalination and power plant. Often, relatively cool water in the area of the plant is found in deeper water where the heating by solar radiation during the day is small. Obviously, the effluent contributes heat to the seawater in the area close to the outfall.

Similar considerations are also valid for the salinity. The intake of relatively low saline seawater is advantageous for the desalination process. Generally weak salinity gradients exist in surface seawater, with the highest salinity near the seabed. Again, the salinity near the outfall of the desalination plant is higher than the natural salt concentration.

1.2. Temperature and Salinities in Seawater and Effluent

Temperature and salinity influence the density of the water. The combination of temperature and salinity gradients can be complex in the stratified structure of the sea because the paramount stratification parameter is the density difference between water masses. For temperatures above 4°C, the density of water decreases with increasing

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temperature, while the density increases with increasing salinity. This means that the density of hot saline effluent can be lower (buoyant effluent) or higher (sinking effluent) than the density of the receiving water at the depth of discharge.

In practical conditions it has been found that the density of the effluent can be higher or lower than the ambient water, depending on the operational conditions of the desalination and power plants. The operation modes can be different because of seasonal conditions. In some cases the density difference between ambient seawater and the effluent from an outfall can change from positive to negative in different seasons or because of different plant operations (maintenance or different demand of power and tap water).

The positive or negative density difference can also depend on the seawater reference in the ambient if (natural) density stratification occurs. The behavior of the effluent after discharge can be quite different depending on the vertical location from where the discharge takes place.

The features described above indicate the importance of knowledge and modelling the natural temperature and salinity distribution in the relevant sea area in the design phase of a desalination plant, and modelling the temperature and salinity rise in the seawater (and specifically near the seawater intake) due to the discharge of the hot brine. For the plant itself the temperature rise and salinity rise due to the effluent recirculation are, of course, the most important.

1.3. Marine Conditions near the Plant Site

Desalination plants are located on the shores of seas and estuaries. In almost all cases the tidal currents as well as wind-driven flows are important features in the hydrodynamic description. The wind-driven flows can be distinguished in local wind effects and large-scale effects, the latter being important especially in large water systems, e.g., the Arabian Gulf, the Red Sea, and the Mediterranean Sea. This effect is paramount in the example of the Mediterranean Sea where the tidal currents are so small that the wind-driven currents are far more dominant.

A useful and safe offshore intake/outfall configuration will require a good knowledge and modelling of the marine environments in terms of water levels, currents, and waves including tide and wind effects on these features, bathymetry, seabed material including transport of sand and silt in the coastal zone, morphology, water temperature, and density including the (natural) vertical gradients (stratification).

On the other hand, the possible environmental impact of a plant requires a good knowledge of the environment in terms of biological species and ecosystems, as well as the human activities dealing with the marine environment.

1.4. Modelling

The Introduction on the effects of temperature and salinity differences indicates that a thorough heat and salt dispersion and recirculation study is useful to optimize the intake

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and outfall configuration in order to obtain intake water of relatively low temperature and salinity.

The introduction of marine hydrodynamics leads to a similar conclusion with respect to modelling. One of the most important tasks in setting up a (numerical or physical) model is the calibration procedure for which field data are required.

For the large-scale modelling of the hydrodynamic flow in the water system (and in particular near the plant site) it is a welcome fact that the wind characteristics are reasonably well known in the form of a windrose measured over a long period in an observation station. The same applies to the tidal constituents describing the basic tidal cycle derived from measurements in a station.

The relatively small-scale hydrodynamic numerical model of the coastal area near the plant site is often connected to (or nested in) the large-scale model. The large-scale model delivers the boundary conditions for the small-scale model. The small-scale model needs detailed information on local bathymetry, local wind, and for calibration purposes measured water levels and currents during known conditions. Additional measurements are often necessary in the construction phase of a new desalination plant.

2. Definitions and Characterizations

2.1. Water Regions

2.1.1. Seas and Oceans

The most typical currents in seas and oceans are the reversing tidal currents, leading also to cyclic varying water levels. Tidal currents are usually dominant in seas and gulfs directly connected by open boundaries with the ocean; the tides in the oceans are affected by the sun and moon. For example, tidal currents are dominant in the North Sea which is connected to several wide, open boundaries in the Atlantic Ocean. The tidal currents are clearly weaker in the Arabian Gulf and in the Red Sea where the open boundaries with the Indian Ocean are smaller, and almost negligible in the Mediterranean Sea where the connection with the Atlantic Ocean via the Gibraltar Strait is extremely small. Therefore, currents set up by meteorological conditions are relatively important in the examples of the Arabian Gulf and the Red Sea, and even dominant in the Mediterranean Sea.

The typical deepwater vertical ocean structure consists of the division of the water depth in a relatively well mixed upper layer (epilimnion, mixed by current and wind effect) and an almost stagnant and stratified lower layer (hypolimnion). The vertical density gradients are in general due to temperature differences, but salinity differences may also occur.

2.1.2. Coastal Waters

The hydrodynamic conditions in coastal waters are more complicated than in open water regions as a result of the shallow depth and the coastline. Wind-driven

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circulations can be important and also include the common daily land and sea breezes. Other typical coastal zone features are wave-driven currents (mainly parallel to the coast, in particular in between the surf zone and the shoreline), storm surges, and upwelling and downwelling of water masses.

Density-driven currents and stratified conditions can be important in coastal waters as a result of the inflow of river water (leading to horizontal and vertical salinity gradients) and the strong warming up and cooling down of shallow water during daily solar radiation and nightly heat loss to the atmosphere.

In some cases this deepwater vertical structure extends into the coastal zone if there is sufficient depth. Discharge of effluent and withdrawal of seawater by an intake can take advantage of the deepwater phenomenon of the separate epilimnion and hypolimnion with little exchange.

2.1.3. Bays

Bays are characterized by a small size and a single open boundary with the sea. Tidal currents inside the bay are a result of the varying water levels on the boundary and the subsequent filling and emptying of the bay; these currents are small. Wind effects are usually dominant.

Often the flushing capacity of a bay is small and therefore less attractive for effluent disposal and seawater intake.

2.1.4. Estuaries

Estuaries are characterized by the contact and merging of freshwater from a river and saline water in the sea, resulting in strong horizontal and vertical salinity gradients (in particular the salt wedge) and subsequent density-driven flows.

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