# Chapter 16
# Overview of Coastal Discharges for Brine, Heat and Wastewater

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**Abstract** Environmental impacts of discharges into the marine environment have become a major issue in the United States and the European Union over the past decade. With the growing demand for freshwater, the capacity of seawater desalination systems using the reverse osmosis process is also rapidly growing. Therefore, the discharge of the concentrate (brine) from these facilities requires careful management to avoid the impacts of denser than seawater discharges that can adversely affect marine benthic communities. This section of the book covers new advances in the siting, design of discharge dispersion systems, evaluation of nearshore discharge systems locations, monitoring, and evaluation of environmental impacts of SWRO concentrate discharge systems.

## 16.1 Introduction

Discharges from coastal desalination facilities, power plants and municipal wastewater treatment plants are a major concern for a variety of environmental and public health related issues. Historically, wastewater and thermal discharges have been the major focus. Both are buoyant plumes, but the approach and management of these types of discharges have differed because of the different needs of exchanging heat and dispersing contaminated wastewater in ways that minimize both public and environmental health risks. Brine discharges from desalination facilities are considered less of an immediate public health risk, but are more likely to affect local water quality and environmental health, especially benthic and near-bottom marine communities (e.g., Lattemann and Amy 2013).

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Regulations regarding seawater discharges are an important consideration in the design, implementation and monitoring of outfall discharges regardless of type of discharge. The requirements for thermal and wastewater discharges have been quite well worked out. Under the Clean Water Act of the United States, the National Pollutant Discharge Elimination System (NPDES) was established to regulate discharges into US coastal waters, lakes and rivers. The State of California enacted more stringent requirements for dischargers within the state under the California Ocean Plan (California Environmental Protection Agency (CEPA) 2012). Although the plan gives explicit guidelines for the regulation and monitoring of the discharge effects on the receiving environment, the only statement regarding concentrate (brine) discharges is that than that salinity should be monitored. Given the expected increase in demand for freshwater from desalination of seawater, California has been defining more specific guidelines for both intakes and discharges for desalination facilities (State Water Resources Control Board 2014).

While regulations continue to be developed and enacted, the processes for determining optimal designs, siting and monitoring for coastal desalination efforts need to be established. Much effort has already gone into the design and optimization of outfall characteristics. Siting of discharges for desalination, wastewater and thermal effluent continue to require optimization (e.g. Lattemann and Hopner 2008). This process includes the integration of policy requirements, modeling efforts that provide for optimal design and siting, and once constructed and operational, ongoing monitoring efforts that evaluate both short-term and long-term effects of the discharges.

## 16.2 Nearfield Considerations

The consideration of the nearfield dispersion of dense brine plumes is an extension of the preceding work on nearfield dispersion from buoyant wastewater and thermal plumes. The well known RSB model for wastewater effluent discharge was developed from a series of laboratory experiments that provided parameterization of key processes affecting the nearfield performance of buoyant plume discharges based on laboratory flume or tank models (Roberts et al. 1989a, b, c). Similar laboratory efforts were incorporated into the Cormix model developed by Jirka (e.g. Jirka and Harleman 1979; Donneker and Jirka 2001). More recent work on brine discharges has focused on the optimization of outfalls for discharge of dense brine effluents and attaining desired dilutions in the nearfield (e.g., Bleninger and Jirka 2008; Roberts et al. 1997). Comparison of field observations with the nearfield models has indicated that model performance is generally very good, and the scaling of the models from the small scale laboratory studies to the field scale of coastal discharges indicate that there may be discrepancies between in situ measurements of the effluent plumes and in situ plume measurements (e.g. Petrenko et al. 1998). But in general the nearfield models provide a reasonable prediction of the likely nearfield impacts.

A comprehensive overview of brine outfall configurations and their implications to the nearfield are presented in Chap. 17. Experimentation with various types of discharge ranging from single port to various configurations of multiport diffusers has provided a better understanding of how to design and implement dense water outfalls so that effective dilutions and zones of initial mixing can be achieved. Chap. 19 evaluates some basic configurations for brine water discharges that provide guidance in the design of these discharges. Numerical modeling of the complex flow associated with outfall diffuser jets remains to be a challenging effort. Therefore, laboratory modeling and dimensional analysis continue to be fundamental tools in evaluating the performance of marine outfalls.

## 16.3 Farfield Considerations

Farfield concerns have been much more difficult to assess, in part because they cannot be easily studied in laboratory and early coastal models were relatively coarse, and not necessarily verifiable. Connolly et al. (1999) published results from a coastal model that was locally driven to describe possible sources and pathways of transport of coliform bacteria onto Waikiki Beach in Honolulu, HI, USA. Simpler approaches for the same area used a progressive vector approach that assumes a uniform spatial distribution of the flow field relative to the measurement points (Roberts 2001). Significant improvements in computing resources and real-time and retrospective data assimilation of both atmospheric forcing and in situ observations have enabled sophisticated, highly resolved 3-dimensional computer models of the coastal environment. These models provide high spatial resolution and with realistic forcing and coupling to the regional and global ocean, more typical coastal dynamics. These models often rely on the nearfield models such as RSB (e.g. Roberts 1989a b, c; Roberts 1999; or Donneker and Jirka 2001) to provide the starting point of plume height, thickness and dilution. In shallow, well mixed coastal areas an integrated, two dimensional models may provide good evaluation of the farfield transport of the plume (see Chaps. 18 and 20). Various types of dynamic modeling are being used for coastal simulations where the models are incorporating the larger scale ocean circulation, regional and local wind fields, with various adaptations that provide advantages for particular questions. A recent paper by Uchiyama et al. (2014) uses the Regional Ocean Modeling System (ROMS) with a nested 75 m resolution model to examine the dispersion of effluent from two large southern California outfalls.

## 16.4 Monitoring and Environmental Assessment

Our ability to monitor and assess the impacts of coastal discharges has been rapidly evolving. The approach to monitoring and the likely impacts will differ based on whether the discharge becomes a buoyant, neutrally buoyant, or dense plume that will collapse to near the seabed away from the discharge site (e.g., Bleninger and Morelissen, Chap. 18). Buoyant discharges, especially those from large wastewater treatment plants, will likely have two components that affect the approach to monitoring. Short-term, small-scale processes may affect the areas very close to the outfalls beyond the initial dilution field but before significant environmental dilution of the plume has occurred. Longer-term processes such as the mean circulation and integration of the discharge into the larger environmental area may make significant modifications to the area. A recent paper by Howard et al. (2014) outlines the contribution of major ocean wastewater outfalls to the regional nutrient budget for the Southern California. Surprisingly, the nutrient contribution from outfalls rivals the flux from coastal upwelling for regions within about 20–40 km from the mainland of the Southern California Bight. Despite years of sustained monitoring in the region, the scale and spatial extent of the effluent contribution to the regional nutrient budget has only become clear in recent efforts.

Lattemann and Amy (2013) lay out criteria and recommendations for establishing an adequate monitoring plan for brine discharges. Much of the suggested effort relates to long-term biological assessment of the discharges on the environment. However, assessment of the overall dispersion of these discharge plumes and their influence on the regional environment can only be achieved with long term sustained observations that are now feasible with the use of autonomous vehicles. Van der Merwe et al. (2014) described the used of short-term AUV deployments for evaluation of the dispersion of brined discharge plumes. Chap. 23 discusses longer term deployments to build a statistical resource that can be used for comparison with complex model statistics, evaluation of statistical impacts on the region, etc.

## 16.5 Conclusions

Despite many efforts, we are still in a stage of developing better resources for evaluation, design, implementation and monitoring of various types of discharges into the marine environment. Because of the complex coastal environment where there are multiple activities that include power plants, desalination facilities, and wastewater treatment plants, integrated planning, analysis and eventually monitoring should take into consideration the multiple uses of the coastal environment.

Both nearfield and farfield modeling provide valuable tools for planning the design of new facilities as well as evaluating the performance of existing facilities. Combining these with additional resources for site selection and integrated planning could provide the optimal strategies for efficiency, energy conservation, preservation of water quality and conservation of the invaluable natural coastal environments.

The tools for monitoring coastal environments are rapidly changing. We are now able to provide a view of the environment that was impossible ten years ago. How we use these observational tools and incorporate the results into future planning and management efforts is an ongoing process.

The chapters that follow provide some examples of the resources available for modeling, planning and monitoring of the coastal environment in the presence of various kinds of discharges.

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