ENVIRONMENTAL IMPACTS OF INTAKES AND OUTFALLS

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Summary

The possible sources of impacts of desalination plants on coastal ecosystems can be sub-divided into three general categories: (1) physical changes; (2) enrichment with organic material, inorganic nutrients, heat or salt; and (3) introduction of toxic materials.

Physical changes in structure or dynamics of the coastal zone are mostly related to the changes in hydrodynamics and erosion/sedimentation patterns resulting from the construction of the plant and the required dredging of intake and outfall channels. Another important source of impacts is the flow of water towards the intake structure. Millions of fish and invertebrates may become trapped (impinged) on the plant intake screens each year or may pass through the plant (entrainment), often with lethal consequences. The discharge of desalination plants consists of slightly heated brine. In the area close to the outlet the primary and secondary production, the species composition, biomass and nutrient dynamics of aquatic ecosystems may change considerably as a result of changes in physiological processes and behavior of individual species. Toxic materials discharged by the plant can either be acutely toxic or cause chronic or sub-lethal effects. The toxins in desalination plant discharges are heavy metals, dissolved from the plant's piping, and biocides used to control biofouling on heat exchangers.

The most severe impacts on the marine and coastal environment are usually brought about by the destruction of support ecosystems. Mangrove forests, seagrass beds and

coral reefs are important examples of such support systems. The environmental impact assessment (EIA) procedure, as described in this chapter, is a good methodology to predict and assess the potential environmental impacts of desalination plant construction and operation.

1. Introduction

The possible impacts of desalination plants on coastal ecosystems can be sub-divided into three general categories: (1) physical changes; (2) enrichment with organic material, inorganic nutrients, heat or salt; and (3) introduction of toxic materials. Physical changes in structure or dynamics of the coastal zone are mostly related to the changes in hydrodynamics and erosion/sedimentation patterns resulting from the construction of the plant and the required dredging of intake and outfall channels. Enrichment, the addition of already naturally occurring substances to the environment at levels that are not toxic, may lead to changes of the structure and metabolism of the ecosystem, whereas the introduction of toxic material refers to the materials that are either acutely or chronically toxic to organisms.

IMO et al. (1990) concluded that the most severe impacts on the marine and coastal environment were brought about by the destruction of support ecosystems. Coral reefs, mangrove forests and seagrass beds are of extreme importance as a pool of genetic material. The environmental impacts of construction and operation of desalination plants will therefore be discussed with special emphasis on these ecosystems.

In many countries, the environmental impacts of projects have to be taken into account explicitly in the decision-making process. The purpose of environmental impact assessment (EIA) is to determine and present the environmental impacts of a proposed project, plan or policy in such a way that a rational decision can be made about its implementation. Furthermore, the EIA contributes to the reduction or mitigation of adverse impacts by generating a number of project alternatives. Project alternatives may comprise alternative sites, alternative processes or alternative implementation schedules. When executed in an early phase of the planning process, EIA may contribute to an optimization of the project design, from both an economic and environmental point of view.

2. Types of Impacts

2.1. Physical Changes

Physical changes in the coastal zone are related to such activities as site clearing and drainage and filling of wetlands or excavation at the construction site resulting in the direct destruction of terrestrial ecosystems, and to the dredging of intake and outfall channels and the construction of protective structures.

Dredging operations may also result in resuspension of sediments. The degree of resuspension depends very much on the characteristics of the dredged material and on the equipment used. Elevated levels of turbidity are generally confined to the immediate surroundings of the dredge site and decrease rapidly after the completion of the operation. High turbidity may lead to the physical abrasion or clogging of gills of fish. Therefore, care should be taken that dredge plumes do not block migration routes of fish and shrimp. Furthermore, increased turbidity may reduce the light penetration in the water and reduce the photosynthetic activity and so the primary production.

The changes in bottom topography and the presence of protecting structures will also induce a number of secondary impacts: e.g. the alteration of the hydrodynamic conditions and water circulation. This, in its turn, may result in changing patterns of erosion, sedimentation and turbidity. Scouring and erosion may lead to the direct loss of terrestrial habitats. Changing patterns of deposition may result in the smothering and suffocation of benthic organisms and the destruction of spawning areas. Total recovery may require a period between several months and two years.

Mention should also be made of a physical change which is the result of the operation of desalination plants, i.e. the flow of water towards the intake structure. A potential very important impact on the biotic communities near plant intakes is the loss of millions of fish and invertebrates on the plant intake screens each year. An excellent overview of the available literature on the impacts of impingement and entrainment as a result of power and desalination plant operation is given by Kennish (1992). Valuable suggestions are also given by Pankratz (1995).

Vertically rotating intake screens, either drums or bands, with mesh apertures of 5 to 9 mm are commonly used to screen intakes. Impinged organisms and debris are removed by applying pressurized spray. Organisms are usually collected in channels and washed off to open water. Debris is collected for disposal. Various measures have been applied to mitigate impingement. Most successful is lowering the intake velocity, however this usually increases plant operation costs considerably. Other measures are related to either screening of the intake area by fine screens or bunds, to modification of the intake or the intake screens, or to influencing the behavior of the marine organisms in the area. Hocutt and Edinger (1980) give an overview of screen and intake modifications that have been applied. Amongst those mentioned, vertical travelling screens, and velocity caps, which result in horizontal flow that is perceived by fish and allows their escape, are reported to have potential. Other exclusion structures and deflection methods, like wedgewire screens, rotating disk screens, perforated pipe intakes, radial well intakes and rapid filter beds are only practical in some locations. Electrical and acoustical barriers, air bubble curtains and artificial lights seem less promising or may even attract fish Langford (1983), Hocutt (1980).

2.2. Introduction of Heat and Salt

The discharge from desalination plants consists of slightly heated brine. As such, the receiving system is enriched with both heat and salts. In the area close to the outlet, the primary and secondary production, the species composition, biomass and nutrient dynamics of aquatic ecosystems may change considerably as a result of changes in physiological processes and behavior of individual species. Further away, where increases in average salinity and temperature will be very limited, some changes may occur in for example gametogenesis and maturation (Wilson 1988). In general the impacts of enrichment are more serious when organisms in the receiving system are living close to their upper tolerance limits (tropical and semi-tropical areas) and in areas where the volume of the receiving water bodies is small compared to the received discharges, and exchange with open waters is limited (enclosed bays and lagoons).

Calefaction (thermal loading), has a direct impact on marine organisms, but also indirect, by changing the water quality due to the reduced oxygen and nitrogen solubility of the water (see the overview by Kennish 1992). The reduced oxygen solubility and the increased oxygen demand of biota and bacterial respiration may develop anoxia. Stratification due to the plant discharge may result in reduced mixing and increased risks of anoxia.

Fish are able to detect small changes in temperature and to avoid thermal plumes. On the other hand, they may be attracted by the higher temperatures. But, mortality as a result of exposure to too warm water will be rare. Of much more importance is the fact that fish adapt to the higher temperatures in the outfall area and may suffer from heat or cold shock when the temperature in the area suddenly changes due to an abrupt startup or shutdown of the plant.

Information on impacts of changing salinity levels on marine organisms is limited. Marine fish exhibit variable ability in tolerating changes in salinity. As a general rule, the US National Technical Advisory Committee of the Secretary of the Interior recommended that, in order to protect wildlife habitats, salinity variations should not exceed 10 per cent of the natural value (Train 1979).

2.3. Introduction of Toxins

Toxic materials can either be acutely toxic or cause chronic or sublethal effects. The only toxins in desalination plant discharges are heavy metals and biocides. Chesher (1975) reported a marked decreased biological diversity in the vicinity of the outlet of a desalination plant. The observed toxicity was attributed to high copper levels in the effluent. Copper piping in the plant was the source of the metal. Metal contents in the discharges may be extremely high after periods of shutdown. The toxicity of heavy metals varies widely with the metal involved, the form in which it is present, and the target organism.

Biocides, most commonly chlorine, are used to control biofouling on heat exchangers. In-plant chlorination causes massive destruction of bacteria and phytoplankton, exposure to 1.5 to 2.3 mg l^{-1} for 5-10 minutes is lethal for some species. However, generation times of these organisms are short and impacts on the receiving waters will be limited. Since chlorine forms residual organic compounds (e.g. chloramines) it may induce toxicity in the outfall area. According to Chow (cited by Kennish 1992) plants in the USA have to prove to the US Environmental Protection Agency the need for the use of chlorine. If permission is granted, the concentrations of total residual chlorine are not allowed to exceed 0.2 mg l^{-1} and discharges are only permitted for two hours per day.

Laboratory tests by Mattice and Zittel (1976) showed that relatively low concentrations of chlorine result in sublethal responses of most marine organisms. Marine fish experience lethal effect at concentrations >0.01 mg l^{-1}. Raised temperatures generally increase toxicity of chlorine.

3. Impacts on Specific Coastal Ecosystems

3.1. Introduction

Coastal ecosystems can be classified according to their vertical position within the coastal zone.

The intertidal, or eulittoral, zone is a very important zone, in which many organisms specially adapted to a diurnal pattern of inundation and desiccation can be found. Mangrove forests are typical of this zone in tropical areas along sheltered coasts.

The upper littoral zone is defined as the zone between the intertidal zone and the 10 m depth contour. This environment is characterized by its permanent aquatic nature and often has a relatively high primary productivity. The major factor governing this productivity and the occurrence of different plant communities is light. A very important community in this zone, in tropical as well as in temperate and cold regions, is that of the seagrass meadows.

In the lower littoral zone, between approximately the 10 and the 50 m depth contour, the so-called coralline bottoms are encountered next to seagrass meadows, red algae and sponges. Coralline bottoms are formed by calciferous organisms like corals, Bryozoae and calciferous algae (Corallinaceae) and tuber worms. The debris of these organisms is collected together and thus may form a hard substratum of sometimes 1 m thickness.

In the following, mangrove forests, seagrass beds and coral reefs, will be described in some detail. Factors which are susceptible to change, and may initiate higher order impacts (the so-called key factors) will be discussed. Threshold, or no-effect, values are given whenever possible. Key factors may either be physico-chemical or biological and determine the well-being of the ecosystem. Emphasis will be put on those key factors that may be influenced by the construction or operation of desalination plants.

3.2. Mangrove Forests

Mangroves are the typical tidal forests commonly observed along the sheltered shorelines of most tropical and a few subtropical countries. Mangroves are limited on a global scale by temperature and their lack of tolerance to frost.

3.2.1. Salinity

The mangrove environment is typical of fluctuating salinities due to rainfall and evaporation. Although for each species of the mangrove environment optimal salinity ranges can be determined, this has actually been done in very few studies. Field (1987) reviewed these studies for three mangrove species. The maximum growth is obtained at salinities of about 25°/oo seawater. Net primary productivity of mangroves could be expected to fall by at least 50 per cent with an increase in salinity from 25°/oo to 35°/oo, with a further significant decrease in primary productivity at higher salinities (Clough 1986).

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