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Quantifying the efficiency of a mono-port diffuser in the dispersion of brine discharges

Ángel Loya-Fernández*, Luis Miguel Ferrero-Vicente, Candela Marco-Méndez, Elena Martínez-García, José Jacobo Zubcoff Vallejo, &José Luis Sánchez-Lizaso

Department of Marine Sciences and Applied Biology, University of Alicante, PO Box 99, E-03080 Alicante, Spain

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ABSTRACT

Reverse-osmosis seawater desalination processes produce a hypersaline effluent waste (brine) which is usually discharged back into the sea via an underwater outfall. Brine discharges can cause environmental problems due to their high salt concentration, but the effects can be minimised by installing a diffuser structure at the end of the pipeline. In May 2010, a mono-port diffuser was installed at the Nuevo Canal de Cartagena desalination plant pipeline (located in Murcia, Spain) in order to increase effluent dispersion.

The aim of this paper was to characterise the brine-plume dispersion throughout a series of oceanographic surveys that were carried out before and after the diffuser installation (2006–2011), and to quantify the effects of the diffuser on the behaviour and dilution rate of the effluent. The results of six years of operational monitoring were also compared with simulations predicted by a numerical mixing model simulation (CORMIX 1), obtaining high concordance with field data. After the diffuser installation, both field data results and model simulations showed a strong increase in the dilution rate of the brine plume, and a significant reduction in the size of the affected area.

1. Introduction

Reverse osmosis is a commonly used method for obtaining fresh water by means of desalination processes around the Mediterranean Basin [1]. This method is a pressure-driven process, in which seawater is forced under high pressure against a semipermeable membrane which allows pure water to pass through, leaving the brine behind. The concentrated seawater, mixed with some toxic chemicals used in the pre and post -treatment processes, forms the effluent [2]. Generally, the brine is discharged as a hyperdense effluent into the ocean via an outfall [3], causing a negatively buoyant plume over the sea bottom. Reverse osmosis desalination plants can discharge an enormous quantity of brine, causing some negative effects on marine ecosystems [4]. However, these effects can be mitigated by the design of the outfall configuration, thus reducing negative effects to acceptable levels [5].

The *Nuevo Canal de Cartagena* desalination plants' effluent disposal system consists of a submarine outfall pipeline through which the brine is discharged into the sea. As discharge configuration directly affects to the mixing process, different technologies can be used to mitigate the unfavourable effects of the brine discharge on the marine environment [6]. In this case, after five years of discharging through a 1.4 m diameter pipeline, an inclined mono-port diffuser was installed at the end of the pipeline in May 2010, in order to create an inclined dense jet (Fig. 1). Diffusers are mixing devices that increase discharge velocity and turbulence between brine and environmental seawater. Turbulence generates a larger contact surface between the discharged brine and the environmental seawater, improving the mixing process and contributing to a reduction of the affected area.

The hydrodynamic mixing process usually takes place in two different zones: the near field and the far field. Initial dilution occurs in the near-field mixing zone, where discharge configuration and brine physical characteristics influence the mixing action [7]; an appropriately designed outfall can considerably increase the mixing between the brine and the overlying ambient water [8]. The mono-port diffuser was installed to completely change the initial discharge configuration, creating an inclined dense jet and thus enhancing the turbulence and the mixing process in the near-field zone [9]. As the turbulent plume travels away, the jet characteristics become less important, and the three-dimensional treatment of salinity dispersion is almost changed to a two-dimensional treatment. When the jet collapses, it forms a gravity driven plume that spreads over the sea bottom causing the generation of a stratified system. From here, this area is known as the far-field zone, and the degree of mixing depends on the ambient conditions and on the density differences between the hypersaline plume and seawater.

* Corresponding author.
E-mail address: loya@ua.es (Á. Loya-Fernández).

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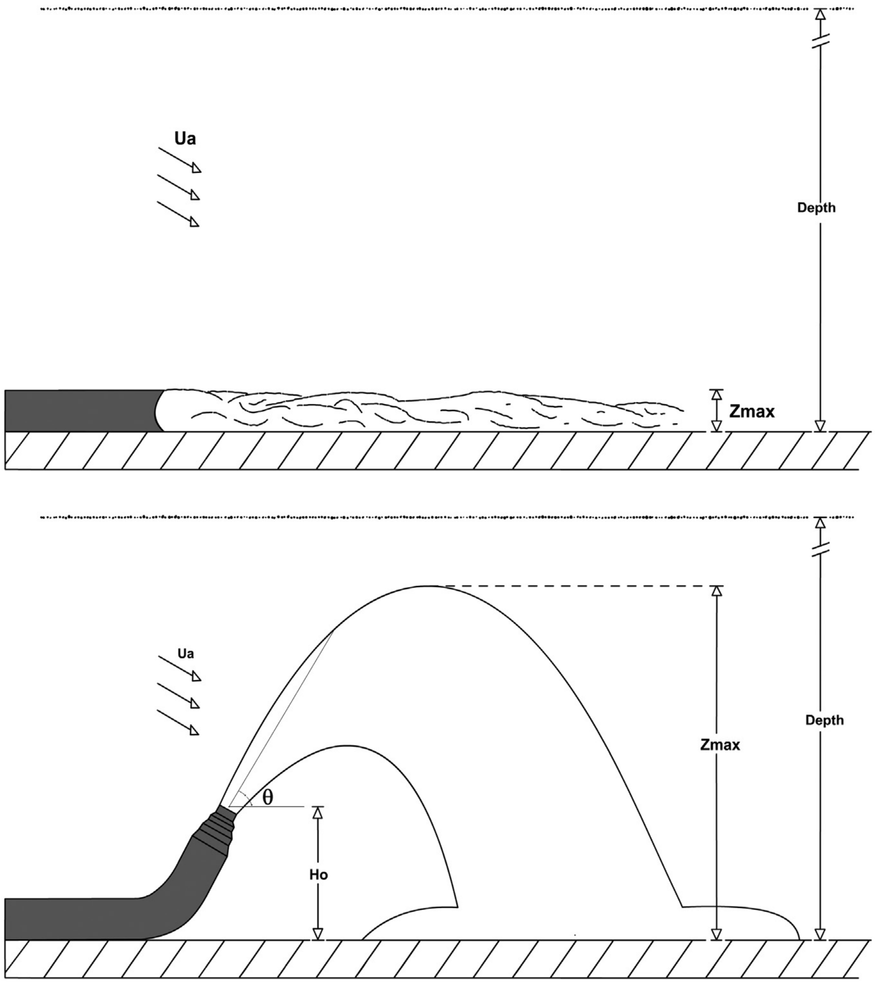

Fig. 1. Schematic figure of brine discharge configuration before (top) and after (bottom) the installation of the diffuser unit at the end of the pipeline in May 2010. Ua: Ambient current speed. Ho: Port height. Zmax: Maximum height reached by the effluent. Depth: Discharge depth.

The picnocline created between both fluids hinders mixing, which is only affected by the passive physical processes of advection and diffusion.

In order to perform a spatiotemporal analysis of the brine plume behaviour, six oceanographic surveys were carried out between 2006 and 2011. The survey data and brine discharge characteristics from the desalination plants were also used to reproduce both simulated scenarios in a far-field mixing zone model (CORMIX 7.0). The content of this work, together with the previous near-field study of the same hyperdense discharge [10], will complete the analysis of one specific brine plume behaviour in both near and far fields.

The main objective of this paper is to quantify the efficiency of a mono-port diffuser on the dilution of a brine discharge, through an analysis of field data and mixing model results. It also includes some discussion about the prediction accuracy of mixing zone models when comparing field measurements with the CORMIX simulations.

2. Material and methods

2.1. Site description

The Nuevo Canal de Cartagena Desalination Plants are located in San Pedro del Pinatar, Murcia, SE Spain. Both desalination plants share a single submarine outfall pipeline. The onshore section of the pipeline covers a distance of 680 m from the facilities to the Mediterranean coast, and the submarine section is 5100 m long, discharging the brine at 32.9 m depth. The combined desalination capacity of both desalination plants is 47.45 Hm^3/year. The salinity of the intake seawater is approximately 37.7 psu and the average salinity of the discharged brine is 63.0 psu, meaning that the conversion factor is approximately 42%.

For five years (2006–2010), the brine was discharged directly through a 1.4 m diameter pipeline resting on the seafloor. However, the installation of the diffuser completely changed the discharge parameters, notably the discharge port height, the vertical discharge angle, and the port diameter (and therefore discharge velocity). The installed diffuser unit is a 60° curved polyethylene cone whose inner diameter reduces to 0.71 m. The diffuser height is 4.56 m.

2.2. Field measurements

An acoustic Doppler current profiler was installed for one month in August 2006, located 100 m away from the discharge point at 34.1 m depth (UTM coordinates X = 701,706 and Y = 4,189,571). It collected data on the average direction of the seawater current and the current average velocity, at two-meter vertical intervals between the sea bottom and the surface [10].

In order to characterise the distribution and dilution rate of the brine plume along its trajectory over the seafloor, a homogeneously-distributed grid with 66 sampling stations was established around the outfall location. One salinity survey was carried out every year between April 2006 and April 2011. The number of sampling stations was increased in each year up to a total of 93 in 2010, in order to enlarge the coverage area and to determine the maximum length of the brine plume (Fig. 2).

The grid spacing between sampling stations was 700 m, but it was reduced to 350 m for the first three kilometers of the plume in order to increase the resolution of the spatial distribution maps obtained from the surveys (Fig. 3). In addition, CT probes (RBR XR-420 CT) were