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Resumos

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Modelação Numérica do Transporte de Contaminantes na Ria Formosa (Portugal)
Numerical Modeling of the Pathways of Contaminants in the Ria Formosa (Portugal)

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SUMMARY

The Ria Formosa lagoon is located in the south of Portugal, and is a barrier island system that communicates with the sea through 6 inlets. This work aims at studying contaminant transport in Ria Formosa in two distinct configurations: before and after Ancão Inlet relocation, through the implementation of the transport models VELA and VELApart and exploration of the models results. The results obtained for both bathymetries suggest better water exchanges through Ancão Inlet and smaller residence times in the western part of Ria Formosa for the new bathymetry. Overall, it can be conclude that Ancão Inlet relocation was a successful human intervention in order to reduce the pollution hazards in Ria Formosa.

1. INTRODUCTION

Coastal lagoons are shallow water bodies partially isolated from the adjacent sea by a sedimentary barrier and connected to the sea, through one or several tidal inlets. These systems usually run parallel to the coastline in contrast to estuaries that are normally perpendicular to the coast.

The Ria Formosa is a barrier lagoon on the Algarve coast of Southern Portugal (Figure 1). This lagoon constitutes a zone protected by a status of Natural Reserve and is a place privileged for the reproduction and development of oceanic species and molluscs, with important economic interest. It also constitutes a natural habitat for various species of birds. This lagoon is an important ecosystem but also a valuable regional resource for tourism, fisheries, aquaculture and salt extraction industries. The urban development around the lagoon places increasing pressure on this system leading to an increase in the lagoon contamination. The pollution increase is more probable in inner and less dynamic areas of the lagoon. The results of this deterioration would affect negatively the tourism, fisheries and the amenity value of the system.

The main aim of this work is to study the potentail pathways of the contaminants disposed from the "Faro ETAR" (station of residual water treatment) and evaluate the impact of the relocation of the Ancão Inlet on the water renewal. The simulation of the pollutant transport and the evaluation of the residence time was made using the models VELA (Oliveira et al., 2006b) and VELApart (Oliveira and Fortunato, 2002), for both bathymetries (after and before the relocation).

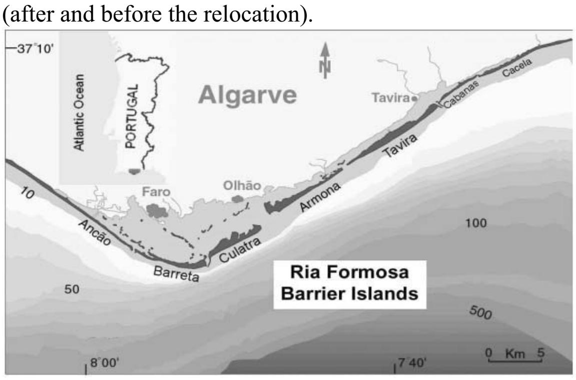

Figure 1 - Location map of the Ria Formosa.

2. MODELS SIMULATIONS

The simulation of the pollutant concentration was performed in order to study its dispersion (VELA) and to evaluate the residence time (VELApart), for both bathymetries (new and old). The models are used here as a 'tool' to analyze the response of Ria Formosa to pollution events. Thus, only a summary of the models information believed to be of greatest relevance will follow. For further details, refer to Oliveira and Baptista (1997), Oliveira and Fortunato (2002) and Oliveira et al. (2006b).

VELA is a two-dimensional depth-averaged model to simulate scalar transport in surface waters, which combines Eulerian-Lagrangian methods (ELM), finite volume and finite element methods. This combination of methods has the advantage of minimizing mass errors. The model can be applied to a variety of problems such as: salinity propagation and instantaneous or continuous localized disposal of mass in estuaries and coastal regions, including wastewaters disposal.

The model VELA, like most ELM models, solves the non-conservative form of the transport equation:

$$\frac{\partial C}{\partial t} + U_i \frac{\partial C}{\partial x_i} = \frac{1}{H} \frac{\partial}{\partial x_i} \left(D_{ij} \frac{\partial c}{\partial x_j} \right) \quad (1)$$

where C is the concentration, t is time, x_i are the horizontal space coordinates, U_i are the depth – averaged velocity components (previously determined by ELCIRC), D_{ij} is the diffusion tensor and H is the total water depth.

The concentration of the pollutant in the near field is assumed to follow a two-dimension Gaussian distribution:

$$C(x.y) = \frac{m}{2\pi\sigma_x\sigma_y H} \exp\left(-\frac{(x-x_0)^2}{2\sigma_x^2} - \frac{(y-y_0)^2}{2\sigma_y^2} \right) \quad (2)$$

where $C(x,y)$ is the concentration at (x,y) due to the near field model alone, m is the mass of the pollutant from the discharge, σ_x and σ_y are the standard deviations in x and y, respectively, H is the total water depth at the discharge point, and x_0 and y_0 define the point of maximum concentration.

This discharge was centered at a grid node, located in the area of the "Faro ETAR", and lasted for approximately 21 days. The distance between the "ETAR" and the Ancão Inlet is approximately 5.5 km. A pollutant concentration of 0.01×10^{-3} $kg.m^{-3}$ was chosen, which is consistent with the concentration of nitrates in this area, due to the release of untreated sewage and industrial and agriculture effluents. The dimension of the circular plume was 100 m of ray, where 80 kg of pollutant were reported following a Gaussian distribution.

The trajectory of the passive tracers was computed using a particle-tracking model in depth-averaged mode (VELApart, Oliveira and Baptista, 1997; Oliveira and Fortunato, 2002), driven by ELCIRC results (Sousa, 2007). In the 2D version, VELApart solves the transport equation (Eq. 1) in Lagrangian form for individual, passive, non reactive particles, forced by the depth averaged velocity field previously determined by ELCIRC (Sousa, 2007). Based on particle pathway calculations, the model also provides residence times (RTs) estimates.

A detailed definition of RTs was adopted, in order to determine a range of realistic values, rather than a single value (Oliveira and Baptista, 1997). Once-through residence times are defined as the time required for a particle released at a particular location in the estuary to leave the system, through a user-defined cross section (Oliveira and Fortunato, 2002).

203 particles were released to a grid node corresponding to the ETAR location. To account for the variability of RTs with tidal amplitude and phase, different initial times were used for particles release: ebb and flood, for a neap and a spring tide for both bathymetries (new and old). The inlets mouths of the lagoon were defined as the domain limits.

3. RESULTS

Figure 2 shows the pollutant dispersion in the Ria Formosa using the two different bathymetries.

The panels of Figure 2 represent the moment when the plume starts leaving the lagoon, showing the pathway followed by the pollutant from the release point to the ocean. For the old bathymetry, the pollutants reaches the inlet 2.5 days after the initial instant (Figure 2a)) and in the new bathymetry the pollutant concentration reaches the inlet 1.8 days after the initial instant (Figure 2b)).

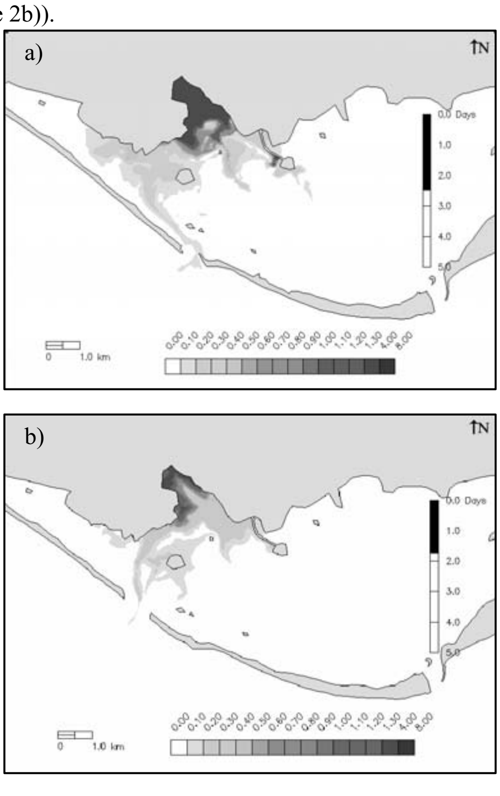

Figure 2 – Representation of the initial instant that the pollutant concentration reaches the inlet. Color bar is the concentration of the pollutant (kg.m^{-3}) (white color represents the initial concentration). Vertical bar is the time (days). a) Old bathymetry of the Inlet (Ancão); b) New bathymetry of the Inlet (Ancão).

It can be observed that the pollutant discharged inside the lagoon reaches the inlet faster in the new bathymetry (Figure 2b)), and therefore it is expected that the pollutants will be faster dispersed out of the lagoon in the new inlet configuration. On the other hand, the pollutant spreads more throughout the lagoon in the old bathymetry, increasing the pollution through a larger area. As expected, the highest pollutant concentration was found near the injection point. The pollutant concentration decreases very rapidly in the inlet zone in both bathymetries.

Table 1 - Average residence time in days for different situations.

	Spring Tide		Neap Tide	
	Flood	Ebb	Flood	Ebb
Old Bathymetry	8.58	8.13	8.79	8.17
New Bathymetry	5.16	4.96	5.33	5.21

The residence time results are summarized in Table 1. These results illustrate the time taken by the particles to leave the lagoon. The particles are released in spring and neap tides, both in the beginning of the flood and ebb periods.

In general, the residence times are larger when particles are released during neap than during spring tide.

For the old bathymetry during the flood in spring tide, the residence time is 8.58 days, for the ebb is 8.13 days. In neap tide, the residence time during the flood is 8.79 days and for the ebb is 8.17 days.

For the new bathymetry during the flood in spring tide, the residence time is 5.16 days, for the ebb is 4.96 days. In neap tide, the residence time during the flood is 5.33 days and for the ebb is 5.21 days.

Independently of the instant within the tidal cycle where particles are released, it can be observed that in the old bathymetry the residence time is always higher than in new bathymetry.

Analysing the residence times in the different tidal cycles, it can be observed that in neap tides the residence time is greater in both bathymetries (e. g. spring tides: 5.16 days and neap tides: 5.33 days in the new bathymetry; spring tides: 8.58 days and neap tides: 8.79 days in the old bathymetry). This happens because in the spring tides the total flow (tidal prism) of the Ria Formosa is larger, producing higher tidal velocities. Therefore, the time delay for the water renewal in the estuary is larger (in neaps). These results confirm others results obtained in the Óbidos Lagoon (Oliveira et al., 2006a) and in the Ria de Aveiro (Dias, 2001), where the residence time calculated for spring tides are lower than those for neap tides.

It has been shown in this work that the inlet relocation has several advantages, such as decreasing the water pollution inside the lagoon due to the contamination originated at "Faro ETAR".

4. CONCLUSION

The models VELA and VELApart were successfully implemented and used for Ria Formosa, constituting an useful tool to study contaminant dispersion in this lagoon.

The results obtained reveal that the human intervention at the new Ancão Inlet promotes a better water renewal in Ria Formosa, reducing the pollution hazards in this coastal system.

The human intervention at the new Ancão Inlet (its opening) contributes to decrease the residence time of the lagoon and to limit the area of influence of pollution events at "Faro ETAR".

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