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ESTIMATION OF WATER EXCHANGE BETWEEN THE BAY AND SURROUNDING SEA

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The simplest one layer model of water exchange between the bay and surrounding sea is considered. The considerations are illustrated with the example of salinity dilution in the bay of Kaštela.

MODEL

The possibility of defining the simplest model of water exchange between the bay and surrounding sea will be considered in order to estimate the density field of some property with a continuous source in the bay. It will be one layer model.

For the steady state the mean current at the cross section of the bay must be zero because the mean water volume in the bay does not change. The mean transport of the property in examination is diffusive and equal to the intensity of the source

(1) $$I = -aD \frac{\delta \overline{C}}{\delta n}$$

where I denotes the intesity of the source, a is area of the cross section on the open boundary of the bay, D is diffusion coeficient and $\delta C/\delta n$ is mean density gradient of the property in examination normal to the cross section.

In front of the bay the continuity equation for the steady state can be written as

(2) $$U\, \delta C_m/\delta Y = K\, \delta^2 C_m/\delta Y^2$$

where the Y axis goes along the coast in the direction of the mean uniform flow U (Fig. 1.), K denotes the diffusion coefficient along the Y axis and C_m is the density of the property in examination. The solution of the equation will be

(3) $$C_m(Y) = \begin{cases} \overline{C} \exp(YU/K), & Y > 0 \\ \overline{C}, & Y \leqq 0 \end{cases}$$

where $Y = 0$ is in front of the bay and boundary conditions are $\lim C_m = 0$ when $Y \to -\infty$ and $\lim C_m < \infty$ when $Y \to \infty$ and $C_m(Y = 0) = \bar{C}$. The solution is in agreement with observation and means that in downstream direction, where diffusion and advection act in the same direction, the steady state can be obtained only if the gradient is zero and in upstream direction the density decreases exponentially. The total transport is in the downstream direction and is equal to the intensity of the source

(4) $$\bar{L}\bar{H}U\bar{C} = I$$

where $\bar{L}$ and $\bar{H}$ are defined as follows

(5) $$\int_0^\infty C(X, Y, Z)\, dZ = \bar{H}\,\check{C}(X, Y)$$

$\bar{H}$ denoting mean depth of the field C and $\bar{L}$ denoting mean distance of field $\check{C}$ from the coast, where X coordinate axis is normal to the coast and Z axis is depth.

The simplest model of the field C (X, Y, Z) is

(6) $$\bar{H} \int_0^\infty \check{C}(X, Y)\, dX = \bar{H}\,\bar{L}\, C_m(Y)$$

where $\bar{L}$ the measure for the distance from the coast up to which the influence of the bay can be detected. From the equation (1) it will be

(7) $$C(X, Y, Z) = \begin{cases} C_m(Y)\,(1 - X/L)\, f(Z), & X \geqq 0 \text{ and } X \geqq L \\ 0, & X > L \end{cases}$$

and from the equation (4) it will be

(8) $$aD\bar{C}/L = I$$

Hence from (8) and (9) the distance from the coast up to which the influence of the bay can be detected is

(9) $$U\,\bar{H}\,L\,\bar{C}/2 = I$$

while the mean density of the property in examination at the open and

(10) $$L = (2aD/\bar{H}U)^{1/2}$$

of the bay is

(11) $$\bar{C} = I\,(2/\bar{H}aDU)^{1/2}$$

On the basis of these very simple speculation it is possible to expect that

i) the distance from the coast up to which the influence of the source in the bay can be detected does not depend on the intensity of that source but only on the dynamic characteristic of the region,

ii) the constant of proportionality between the intesity of the source and mean concetration on the open end of the bay also depends only on the dynamic characteristics of the region.

This means that L and $\bar{C}/I$ possibly can be measured in the field of suitable quantity with a continuouse source in the bay and the results can be applied to density field of other quantity.

For the estimation of $\overline{C}/I$ and L one can use known diffusion coeficient in the equation (10) and (11) and supposing that the bay is sufficiently large so that the considered quantity at the open end of the bay will be vertically well mixed, H will be bottom depth.

Integrating the equation (1) from the open end of the bay to the interior and assuming, where it is possible, a = const. one obtaines linear increase of $\overline{C}$ in the bay. For the estimation of the field $\overline{C}$ in the bay this also can be useful.

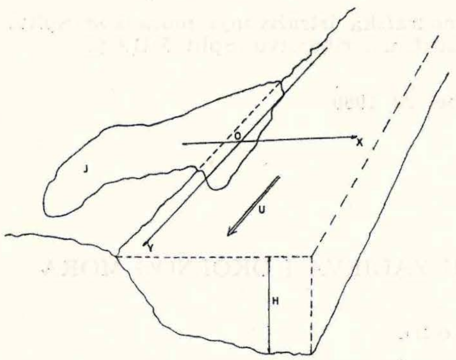
SALINITY DILUTION IN THE BAY OF KAŠTELA

The river Jadro flowing in the Kaštela bay decreases the salinity of water in the bay compared to that of the surrounding sea. Approximatively the difference of mass of fresh water on the mass unity of sea water between the bay and the surrounding sea will be

(12) $$\overline{C}\ \mathrm{kg/m^3} = S - S_b\ ‰$$

and can be interpreted as density of fresh water from the Jadro.

The Fig. 2. shows the Kaštela bay with the hydrographic station on which the measurement of data given in the table 1. was carried out (Zore-Armanda *et al.*, 1974). On the same figure are also given the dimensions of interest.



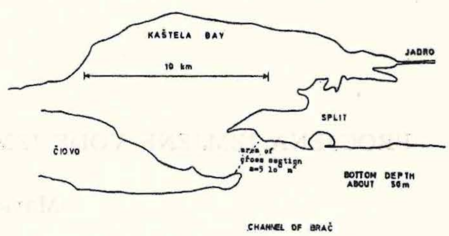


Fig. 1. Coordinate system of the model Fig. 2. Kaštela bay

Table 1. Mean annual current speed and salinity

Station	current m/s	salinity ‰
6	.04	37.32
10	.06	37.42

For diffusion coeficient K one can use relation known from similarity theory of turbulence (Landau-Lifšic, 1965)

(13) $$K = u/k$$

where u is current speed in the bay considered as standard deviation of velocity fluctuations and k is wave number of velocity fluctuations corresponding to the dimension of the bay.

From Fig. 2. on which horizontal dimension of the bay are given k must be of order of magnitude 5×10^{-4} m^{-1} and four u = 0.04 m/s from table 1., from table 1., (13) it will be D = $10^2 m^2/s$. The mean annual river inflow from the Jadro is I = 8×10^3 kg/s of fresh water (Buljan and Zore-Armanda, 1971). From Fig. 2. a = 5×10^8 m^2, H = 5 10 m and from table 1. U = 0.06 m/s. Putting this value in the equation (11) one obtaines $\overline{C} = 10^{-1}$ ‰. This result is in accordance with the values of salinity given in the table 1. because from the equation (10) it will be L = 2×10^4 m which demonstrates that in the equation (12) the salinity difference between the stations 6 and 10 are representative and one can consider the station 10 to be out of the influence of the bay.

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KRATKI SADRŽAJ

Razmatran je problem procjene izmjene vode između zaljeva i otvorenog mora na jednoslojnom modelu stacionarnog strujanja. Izvedene relacije ilustrirane su na primjeru dilucije morske vode u Kaštelanskom zaljevu dotokom rijeke Jadro.