

2-D MODEL FOR POLLUTANT DISPERSION AT THE COASTAL OUTFALL OFF PARADIP

A. Suryanarayana, M.T. Babu, P. Vethamony and A.D. Gouveia
National Institute of Oceanography, Dona-Paula, Goa

Abstract

Simulation of dispersion of the effluent discharge has been carried out using 2-D Model to verify the advection and diffusion of the pollutant patch of the proposed effluent disposal off Paradip. The simulation of dispersion was performed for low wind speed conditions when mixing is expected to be minimum in the region. Based on the model results the pollutant patch moved and diffused parallel to the coastline in the direction of the along-shore current.

Introduction

The model study is carried out for the shallow water region off Paradip, where the tides and local winds play an important role in determining the advective processes. The tides and wave action are moderately high in this region. The currents are parallel to the coast and relatively weak near the coast, however, a gradual intensification towards offshore is the conspicuous feature of the structure of coastal currents in this area (Anon, 1988a). Based on the prevailing physico-chemical and geomorphological features of the study area a point located at 1.2km distance from the landfall point has been suggested suitable for the disposal of the effluent. In the present study, we made use of a numerical model to investigate the advection and diffusion of the effluent disposal at the proposed outfall point off Paradip.

Model

The governing equations are based on the conservation principles of continuum mechanics (ACRi 1994) and employed the shallow water approximation to the Navier-Stokes equations. The horizontal plane is represented by x-y in the cartesian co-ordinate system. The initial and boundary conditions, bathymetry, tides, wind fields, atmospheric pressure, bottom friction and values of sources and sinks are allowed to vary over the spatial grid. The flow equations are solved using a modified form of the coupled Alternating Direction Implicit (ADI) method (Leendertse, 1970). For water quality parameters the method of Nodal Point Integration (NPI) is employed to integrate the governing differential equations by temporal and spatial discretization over each element of the physical domain.

All the state variables, except for velocity are defined at the grid nodes. The velocity components, U and V (U→ W-E; V→ N-S) are provided at the centre of the grid nodes in the x, y directions.

In order to carry out the simulation of concentration of the effluent disposal, a model domain of 1.95km X 3.5km was selected, the outfall location was kept at a distance of 993m normal to the coast. The orientation of the coastline (62° with respect to the north in this region) is taken in to consideration while computing velocity components. The domain is divided into 70 X 40 square grids with a size of 50 m x 50 m. A time step of 6sec is given based on CFL criterion (Ramming and Kowalik, 1980).

The depth values obtained from the bathymetric survey are assigned at the centre of every grid point. Water

level variation of April 1998 at every 30 minutes are given from the Tide Tables (Anon, 1998b). Currents measured in this region during April 1998 (Fig.1) are used as boundary conditions along the three open boundaries i.e. east, north and south (onshore component, representing west nearly zero). An average wind speed of 3m/s and direction 240° representing southwesterlies are considered in the model.

The specifications of the effluents are as follows

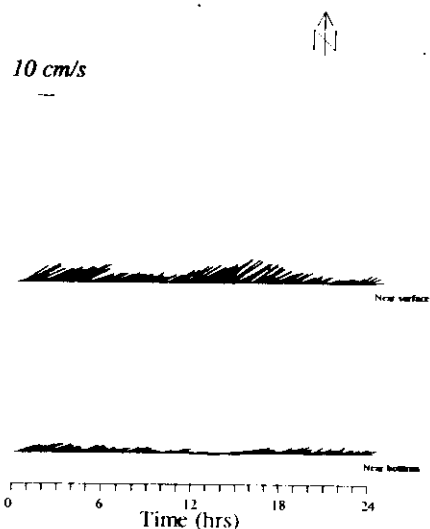
The initial concentration = 1.0kg/m^3 ; temperature = 30°C ; density = 1.08g/cm^3 ; rate of discharge = $13330\text{m}^3/\text{day}$.

Results

A continuous discharge of effluent is introduced at the outfall after 5400 sec when the model stabilised. The results of the model are shown in Figs. 2-7. These figures show the variation of effluent concentration after 30min, 1hr, 2hr, 6hr, 12hr and 24hr of discharge.

The marine outfall is kept 993m away from the sea wall (coastline for the model). The patch of pollutant advanced and diffused parallel to the coast. After 12hrs the initial concentration of the effluent reduces up to 0.0020kg/m^3 and the patch moves towards east-north-east direction following the along-shore current direction which has a maximum speed of 31.3cm/s . The onshore components are weak (0.039cm/s) during April in this region.

Fig. 1 Observed currents on 20 April, 1998 used for simulation of effluent dispersal



The above model results of April 1998 show that the pollutant patch moves parallel to the coastline and the concentration of the pollutant reduces accordingly. This condition is favourable to establish the outfall at the proposed location. However, we have to consider the behavioural aspects of the pollutant patch during other months of the year. This model can be applied to verify the dispersion of pollutant patch during other seasons.

Fig. 2 Concentration of the effluent after 30 minutes (depth contours are in meters)

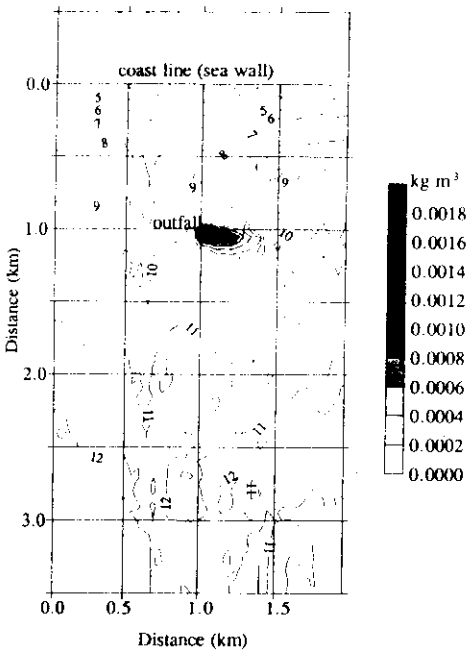


Fig. 3 Concentration of the effluent after 1 hr (depth contours are in meters).

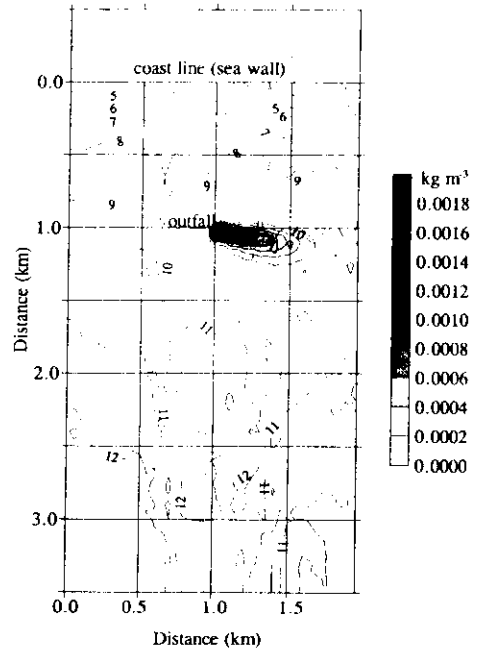


Fig. 4 Concentration of the effluent after 2 hrs (depth contours are in meters).

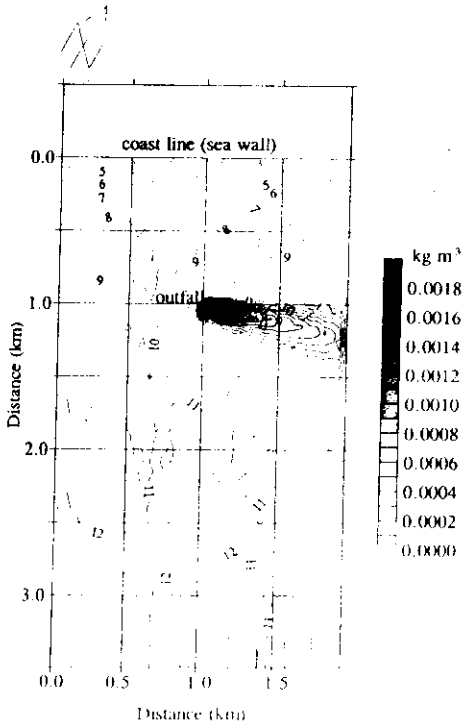


Fig. 5 Concentration of the effluent after 6 hrs (depth contours are in meters).

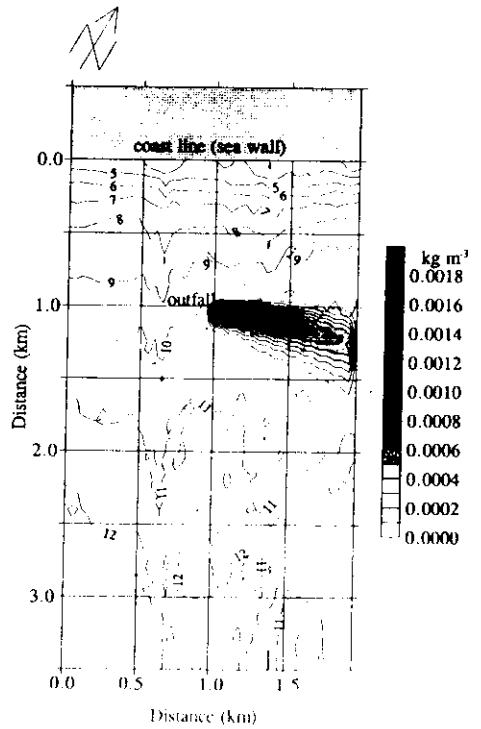
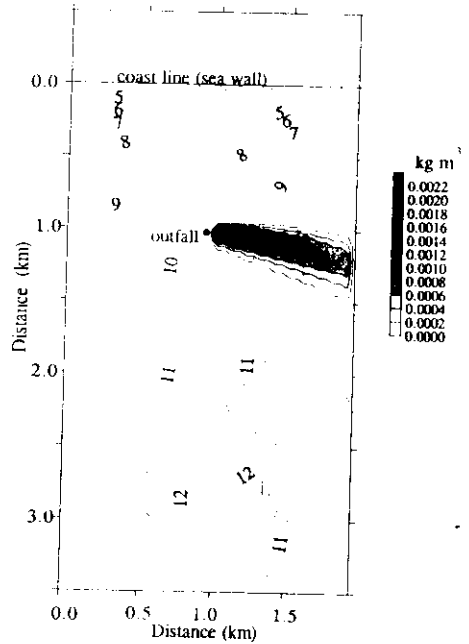
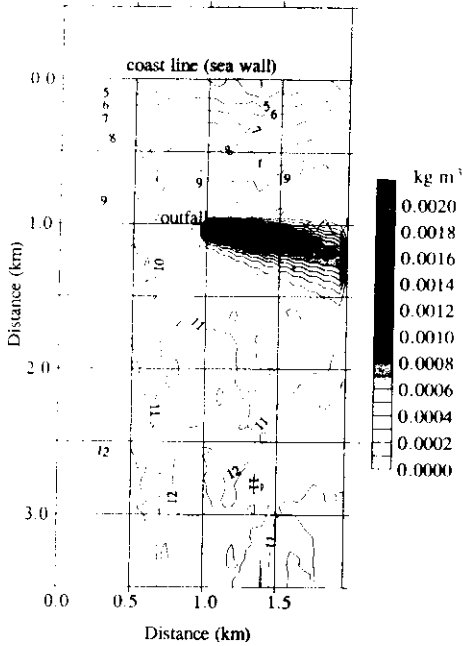


Fig. 6 Concentration of the effluent after 12 hrs
(depth contours are in meters).

Fig. 7 Concentration of the effluent after 24 hrs
(Depth contours are in metres)



References

1. ACRI, (1994): "Tidal" users Manual, version 2.50, Analytic and computational Research Inc., Los Angeles, USA
2. Anonymous (1998a): Tide Tables Part I. 1998; Pub. Surveyor General of India, office of the Geodetic and Research branch, Dehra Dun, India.
3. Anonymous (1998b): Rapid Environmental Impact Assessment of Marine activities for the proposed Fertilizer Plant at Paradip, Orissa, No. NIO/SP-25/98
4. Leendertse, J.J. 1970: A water quality simulation model for well-mixed Estuaries and Coastal Seas: Volume 1, Principles of computation, Rand Corp. RM-6230-RC.
5. Ramming, H.G. and Z.Kowalik, 1980: Numerical modelling of marine Hydrodynamics; Elsevier Oceanographic Series, 26, pp.368.