

Modelling Ballast Water Transport

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Ballast water discharges in the coastal environs have caused a great concern over the recent periods as they account for transporting marine organisms from one part of the world to the other. The movement of discharged ballast water as well as the species within it, largely depends on the prevailing hydrodynamics of the receiving water body. Modelling the hydrodynamics of marine environment will lead to reasonable and reliable prediction of the movement of the ballast water discharges. A case study has been carried out for the Gulf of Kachchh region on the west coast of India, where there are many minor ports and one major port are situated, using a two-dimensional hydrodynamic model - MIKE21. Tidal forcing and a constant wind field have been prescribed in the model to generate the general circulation pattern. The fate of discharged Ballast water plume at three locations in the study region has been modeled using the advection-diffusion processes. The model results show that the ballast water discharged near the shore tends to move alongshore and that discharged in the mid-gulf traverses back and forth in the channel and eventually spread towards the northern shore.

Key words: ballast water transport, hydrodynamic modelling, Gulf of Kachchh,

Introduction

Ballast water discharge in coastal water has been a major threat to the native marine biota due to the introduction of exotic species. Though much work on the modes of transport, detrimental effects on the native species have been carried out in some countries, influence on the transport by the local environment have not been reported much in the literature. The present investigation is aimed at studying the impact on the ballast water transport by the hydrodynamics of the local environment. Such studies will facilitate suggesting safe disposal sites and assessing the risks involved with the ballast water discharges in the coastal environment.

Study area

The Gulf of Kachchh, a predominantly tide-driven embayment, is located in the northwestern part of India between 22°15'-23°N and 69-70°15'E (Fig. 1). It is demarcated as one of the macro-tidal regions of the world. The tidal currents during spring are as high as 1.5-2.5 m/s in the central channel and the tide elevation reaches a maximum of about 6.5m at Navlakhi. The Gulf is situated zonally with an east-west length of ~150 km while the width decreases from ~60 km in the west to about 1-2 km in the narrow creeks at Navlakhi in the east. The western open boundary of the Gulf interacts with the northern Arabian Sea while the eastern Gulf opens into the shallow creeks in the Little Rann of Kachchh. Sandy beaches characterize northern part of the coast and the southern coastal region is demarcated by mudflats in the inter-tidal zones. The southern Gulf is famous for coral reefs with areas protected as Marine Sanctuary and National Park. Recently, industrial developments in the northern Gulf has led to the expansion of two ports: one at Mundra, a private port and the other at

Kandla, a major port. There are several minor ports and fishing harbours in the Gulf in addition to jetties, breakwaters, pipelines, water intake, marine outfall and single point moorings associated with refineries. Some of the coastal areas are natural habitats for rich vegetation, especially mangroves.

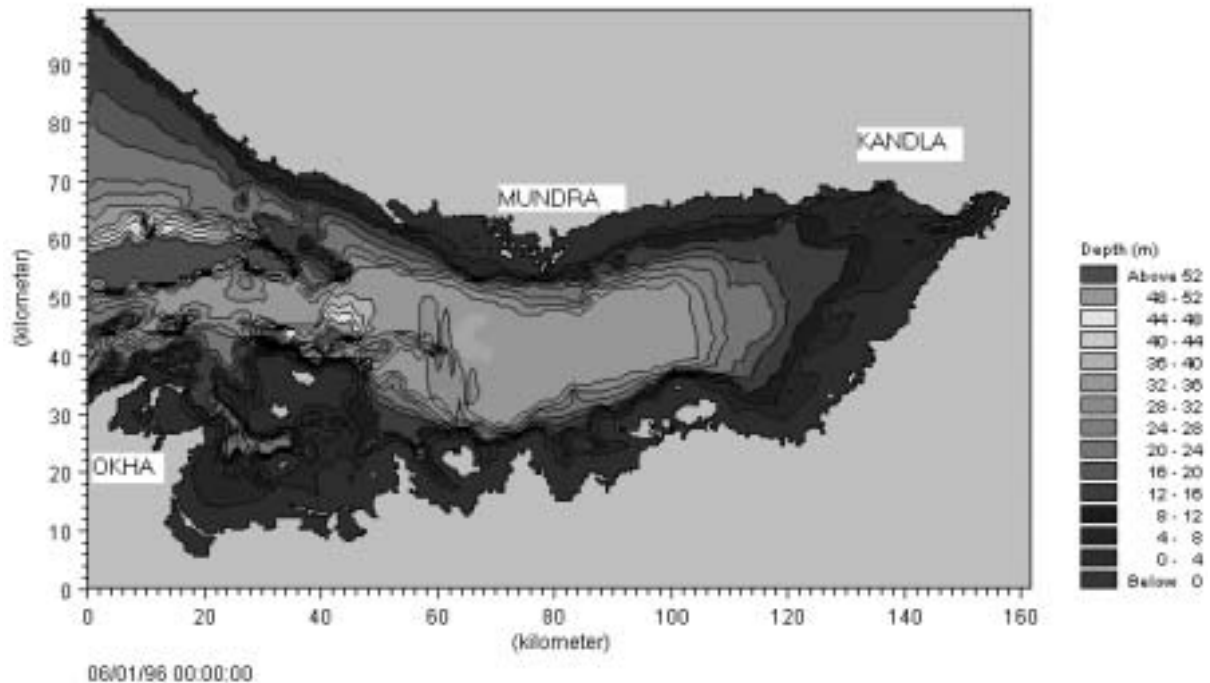


Fig. 1. Gulf of Kachchh: bathymetry and morphological features

Quite a few studies have been carried out in the past to understand the tidal flow in the Gulf. Tidal phase and amplitude have been predicted using harmonic constituents estimated from tide data measured at select locations along the periphery of the Gulf (Panvelkar et al, 1986). Shetye (1999) used an analytical model to study the tidal harmonics and the amplification of the tide due to resonance and geometric effect. Tides and tidal currents were simulated using a 2D model by Unnikrishnan et al (1999). However, studies related to modelling the transport of effluents or discharges in the Gulf have not been reported much in the literature.

Methodology

MIKE21, a 2D hydrodynamic model has been used to study the fate of discharged ballast water in the marine environment. The bathymetry of the region has been taken from the CMAP data and augmented by data from hydrographic charts and bathymetry data available at NIO Data Center, Goa. Tides along the open boundary were generated by toolbox, available in MIKE software, by predicting the water elevation using the four major constituents M2, S2, K1 and O1 at the coastal tidal stations Okha and Godia (International Hydrographic Bureau, Spec. Pub, Monaco). Subsequently the tidal elevations required at the model boundaries were interpolated and used as the forcing parameter. A constant wind of 5 m/s blowing from 45° was applied in the model to represent the prevailing environment during the simulation period. The

hydrodynamics simulation of the area was carried out for a period of 3 days. The model area and the grid spacing are shown in Figure. 2.

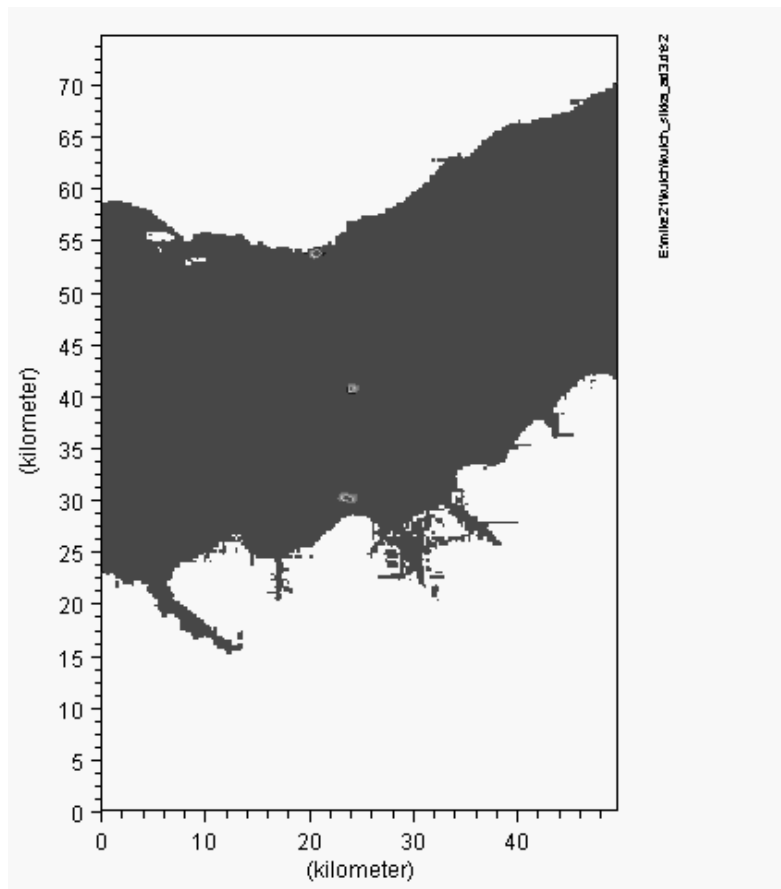


Fig. 2. Model domain and location of ballast water discharges

The model was calibrated and validated with the available data in the study region. After setting up the model, the quantity ballast water (21000 tons) was introduced into the model domain at three locations, viz., near the Mundra port on the northern coast, Mid Gulf and near Sikka on the southern coast (Fig. 2). A discharge of ballast water was considered in this study. Discharge at the Mundra port was restricted to 7h duration, assuming a pumping capacity of 3000 tons per hour and discharge velocity of 2m/s. At other locations, continuous discharge was assumed for simulation. MIKE21AD model was used to study the dispersion of the discharged ballast water at the above three locations.

Results

The hydrodynamics of a water body can better represented by a 3D model as it accounts for the vertical gradients. However, the Gulf of Kachchh is found to be a well-mixed body without much stratification and hence a 2D model was used. The model was validated with the help of measured data of March 1994. Typical current vectors simulated during this period are presented in Fig. 3. The contours represent the water elevation and the arrows show the direction and magnitude of currents.

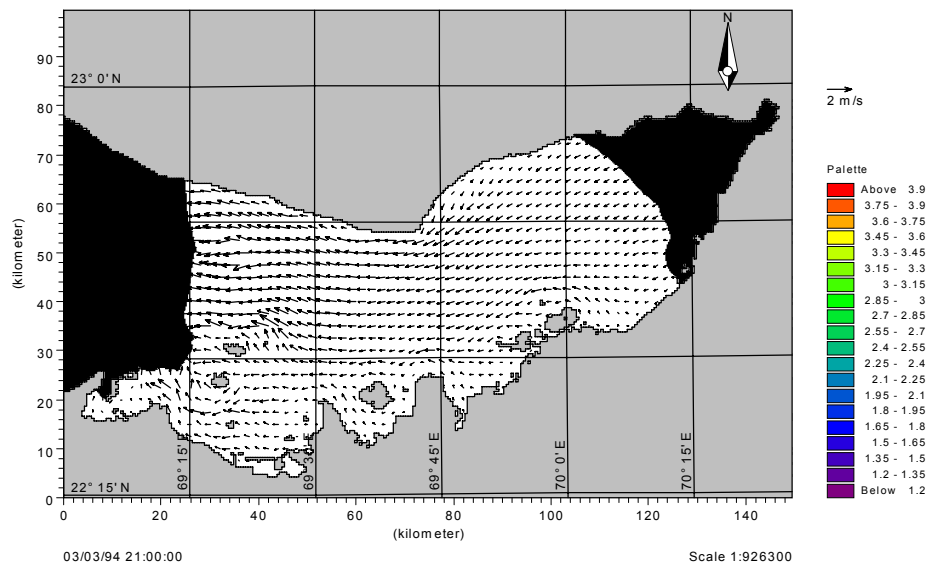


Fig. 3. Typical current vectors in the Gulf of Kachchh

The fate of the discharged ballast water at different time stages from the time of disposal simultaneously at the three locations are presented in Figures 4 - 11.

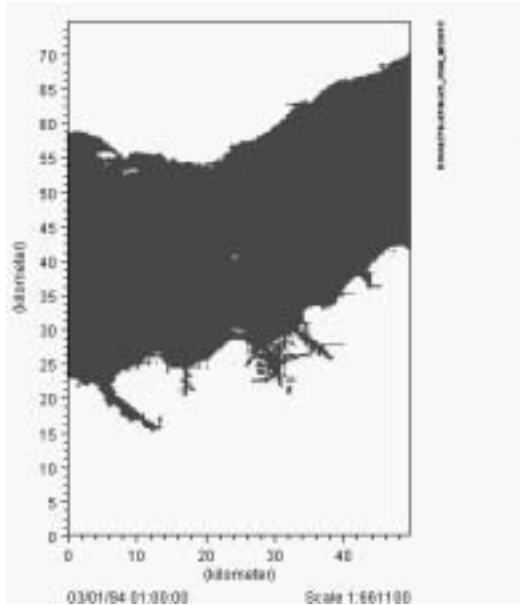


Fig. 4. Extent of discharged ballast water transport after 1 h

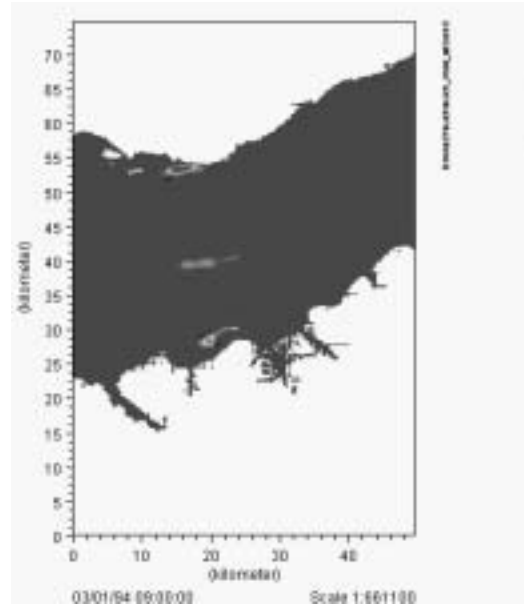


Fig. 6. Extent of discharged ballast water transport after 9 h

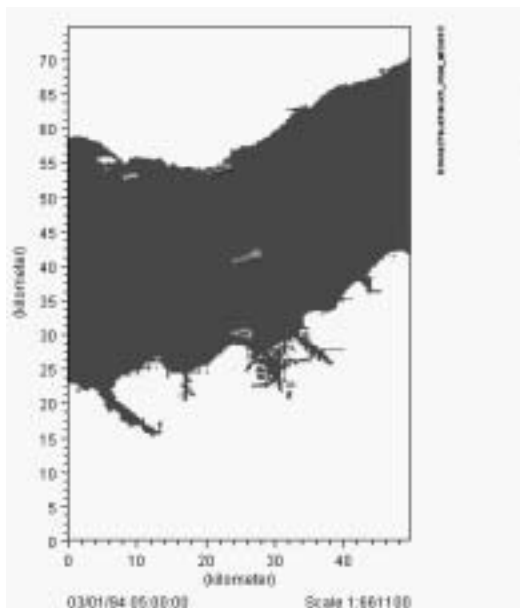


Fig. 5. Extent of discharged ballast water transport after 5 h

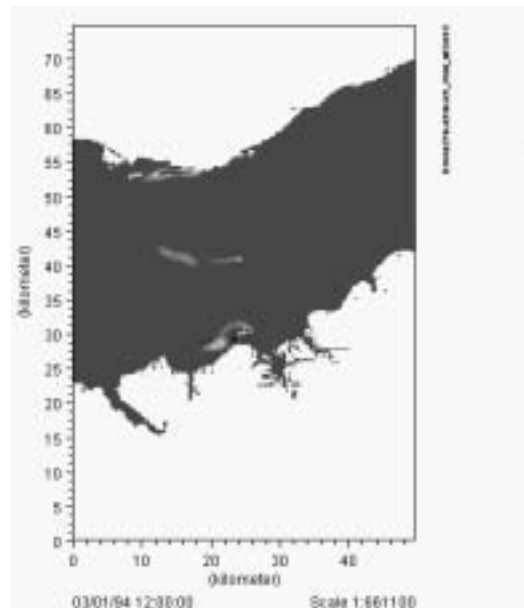


Fig. 7. Extent of discharged ballast water transport after 12 h

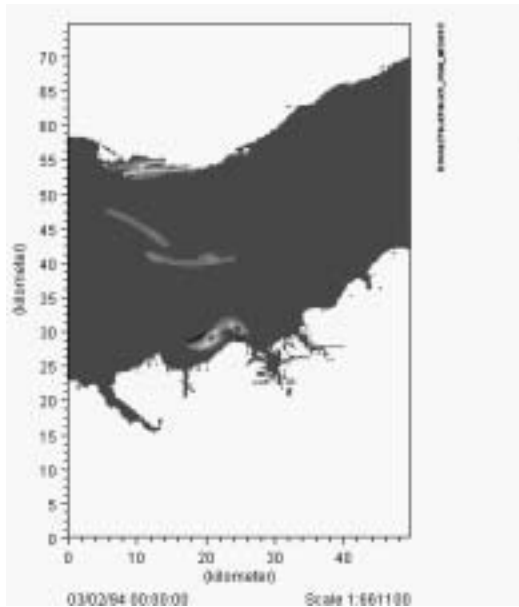


Fig. 8. Extent of discharged ballast water transport after 24 h

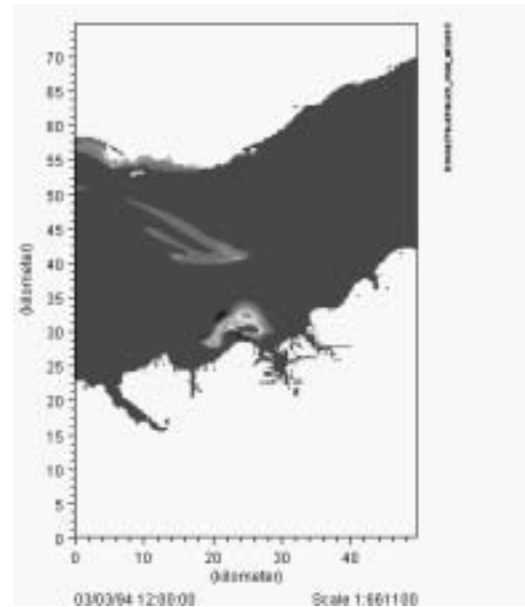


Fig. 10. Extent of discharged ballast water transport after 60 h

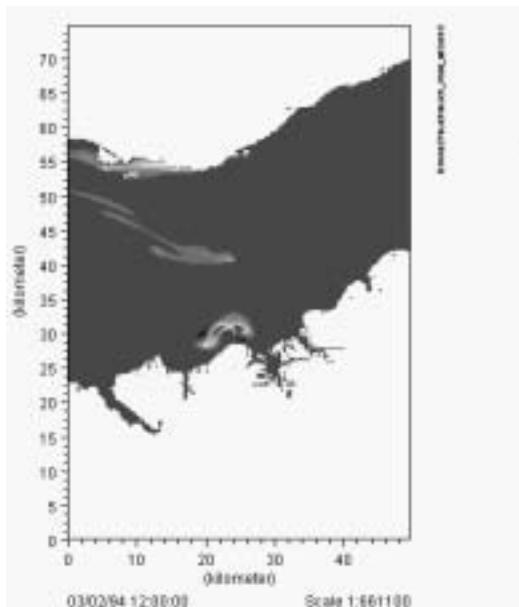


Fig. 9. Extent of discharged ballast water transport after 36 h

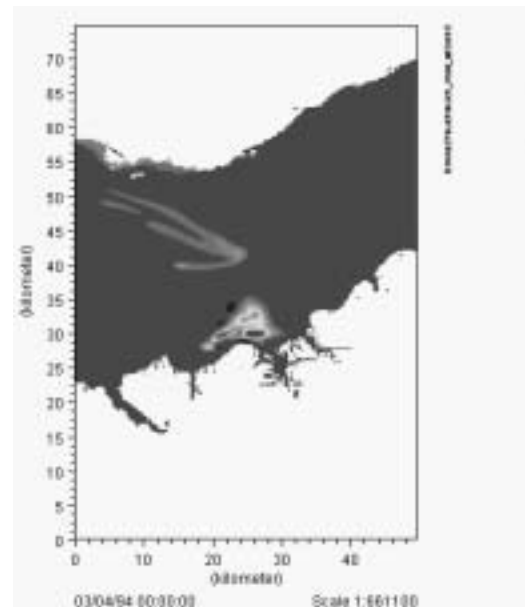


Fig. 11. Extent of discharged ballast water transport after 72 h

Conclusions

From the case study of model simulation on the transport of ballast water discharge in the Gulf, the following conclusions are drawn:

- Transport of the ballast water discharged near the shore is always along the coastline and it does not come into the mid gulf.
- Ballast water discharged in the Mid-Gulf moves along the channel for most of the simulation period, and at the end of 36h it moves northwards and comes close to the shore after 3 days.
- Spreading of the ballast water in the southern coast of the model area is less compared to that on the northern coast.
- Dilution of the ballast water in the southern coast is found to be less compared to that in the Mid-Gulf.
- Ballast water discharged in the Mid-Gulf is found to be moving out of the initial location, whereas that discharged in the northern and southern coasts remain there itself, indicating a caution for the discharge at such locations.
- The extent of ballast water transported in the mid-gulf is the highest compared to that on the northern and southern coasts.

References

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