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Environmental sensitivity mapping and risk assessment for oil spill along the Chennai Coast in India

R.S. Kankara *, S. Arockiaraj, K. Prabhu

Integrated Coastal and Marine Area Management Project Directorate, Chennai 600100, India

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ABSTRACT

Integration of oil spill modeling with coastal resource information could be useful for protecting the coastal environment from oil spills. A scenario-based risk assessment and sensitivity indexing were performed for the Chennai coast by integrating a coastal resource information system and an oil spill trajectory model. The fate analysis of spilled oil showed that 55% of oil out of a total volume of 100 m^3 remained in the water column, affecting 800 m of the shoreline. The seasonal scenarios show major impact during the southwest (SW) and northeast (NE) monsoons and more fatal effects on marine pelagic organisms during SW monsoon. The Oil Spill Risk Assessment Modeler tool was constructed in a geographic information systems (GIS) platform to analyze the risks, sensitivity mapping, and priority indexing of resources that are likely to be affected by oil spills along the Chennai coast. The results of sensitivity mapping and the risk assessment results can help organizations take measures to combat oil spills in a timely manner.

1. Introduction

Oil spills can have adverse impacts on both the environment and society, especially when the spilled oil reaches the shoreline. In order to prevent and minimize the impact of oil pollution, prevention and intervention tools and their effectiveness must be improved upon. Preexisting information on coastal resources and prioritized protection areas allow for a faster response and better distribution of protection and cleanup efforts, thereby facilitating appropriate coastal management (Santos and Andrade, 2009). In the last three decades, the movement of oil spills on the water surface has been studied extensively (Wang and Shen, 2010), resulting in two-dimensional (2D) oil spill models of advection and spreading (Nagheeby and Kolahdooza, 2010). At present, models are commonly used to study oil trajectories for planning or assessment purposes (Galt, 1994, Kankara et al., 2013). Modeling tools have become essential for estimating oil spill hazards and risks not entirely dependent on past incidents (Vethamony et al., 2007).

Remote sensing data have proven very useful in providing information on various components of the coastal environment (Nayak and Bahuguna, 2001). Multispectral images such as Landsat images, albeit low resolution (30 m spatial), are still useful for identifying and classifying coastal resources (Zakir Hossain et al., 2009). The geographic information systems (GIS) can be used to predict the movement and fate of spilled oil, to explore the possibility of different strategies in an interactive manner, to devise responses to oil spills, and to quantify the impacts of oil spill on resources (Kankara and Subramanian, 2007). In oil spill risk assessment, GIS is integrated with a spatial analysis that includes the biophysical characteristics and population vulnerability of a region (Nelson et al., 2015). Early understanding of the potential environmental sensitivity of different types of shoreline, and knowledge of the impact of oil spills on coastal resources, have helped reduce the extent of damage caused by oil spills substantially (Adler and Inbar, 2007). The Environmental Sensitivity Index (ESI), a value-based map, is used to determine the sensitivity of exposed shorelines to oiling (Alves et al., 2014). ESI maps are an integral component of oil spill contingency planning and emergency response (Carvalho and Gherardi, 2008).

In order to deal with oil spill accidents, marine security and safety agencies must have real-time accurate ocean information and a forecast of oil trajectories for the next few days. Observations and monitoring of the spill are needed for initialization of model trajectories, updates, and uncertainty assessment (Marta-Almeida et al., 2013). The oil spill model simulates the oil spill trajectories, statistically characterizing the risk over the study area. In their study, Olita et al. (2012) focus on the risk, because its evaluation includes vulnerability factors. The risk assessment estimates the probability of contact with all identified offshore environmental resources and segments of the shoreline, from locations chosen to represent hypothetical oil spills (BOEM, 2012). The integrated GIS technology is a powerful tool to generate ESI charts of the coastal environment for oil spill contingency plans worldwide (Souza Filho et al., 2009). Several oil spill models have been used in the past three decades based on transport and weathering processes (Mackay et al., 1980). The weathering model ADIOS2 (Automated Data Inquiry for Oil Spills) predicts the changes in oil characteristics occurring over

* Corresponding author.
E-mail address: kankara@icmam.gov.in (R.S. Kankara).

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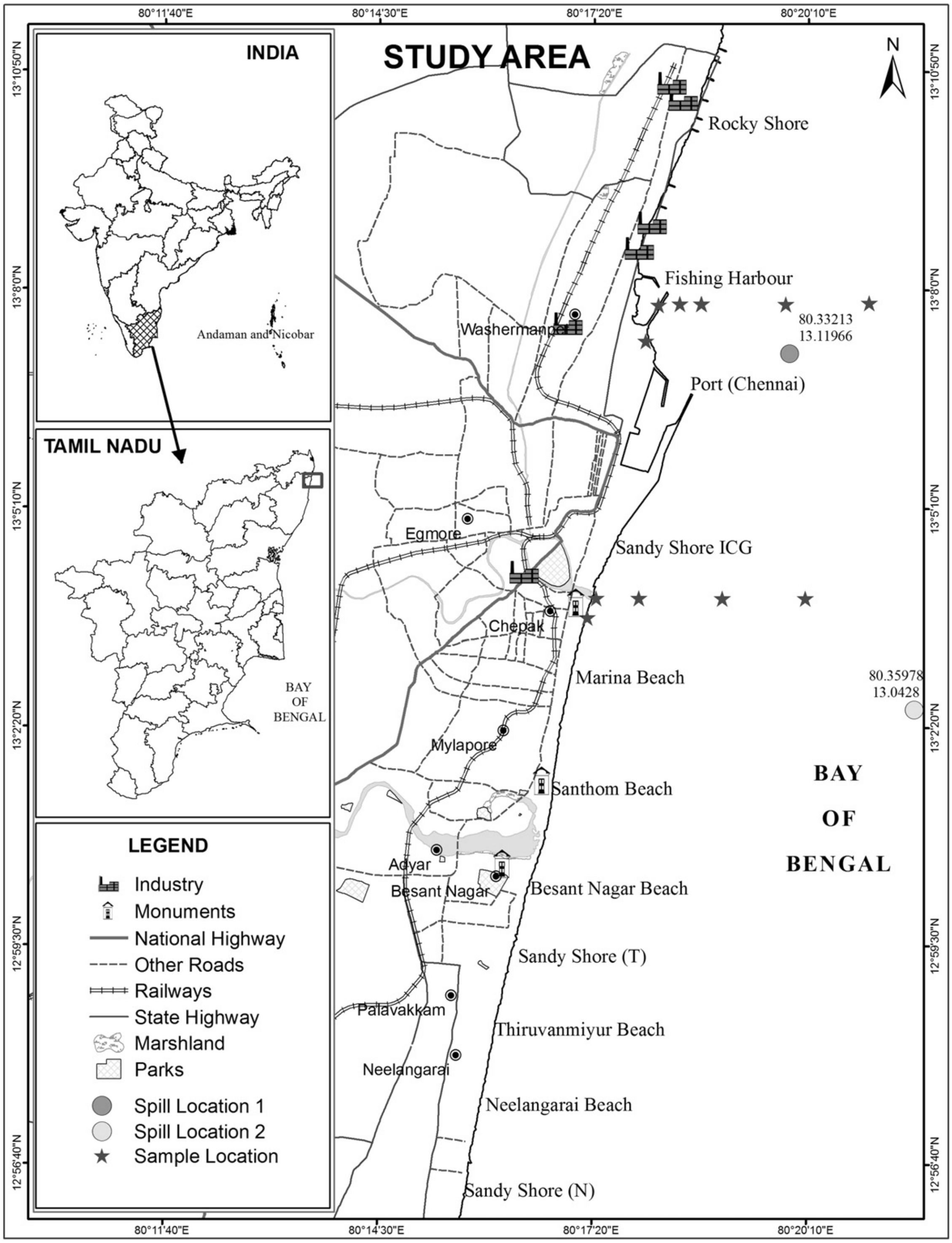

Fig. 1. Study area and sample locations.

time, under the influence of a variety of environmental conditions. ADIOS2 uses mathematical equations and information from the database to predict changes over time in the density, viscosity, and water content of an oil or product; the rates at which the oil evaporates from the sea surface and disperses in water; and the rate at which an oil-in-water emulsion may be formed (Lehr et al., 2002). The model can be used for risk assessment, emergency response, and contingency planning activities related to surface spills often resulting from shipboard activities and accidents, which comprise the majority of oil spills (Deborah, 2003).

The main source of oil pollution in oceans is shipping and maritime activities. Nearly half of the world's oil production is transported via sea (Clark, 1992). The Indian coastal zone is always at a risk of experiencing oil spills. The Arabian Sea and the Bay of Bengal have been estimated to annually receive approximately 5×10^6 and 4×10^6 t of petroleum, respectively, from routine discharges from oil tankers and other ships (Hinrichsen, 2009). In India, oil drills and mobile platforms for drilling in deep coastal waters are manufactured to meet the demands of its growing population. The most recent oil deposits have emerged from offshore areas off the deltaic regions in