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Integrated assessment for establishing an oil environmental vulnerability map: Case study for the Santos Basin region, Brazil

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ABSTRACT

The growth of maritime transport and oil exploitation activities may increase the risk of oil spills. Thus, plans and actions to prevent or mitigate impacts are needed to minimize the effects caused by oil. However, tools used worldwide to support contingency plans have not been integrated, thus leading to failure in establishing priority areas. This investigation aimed to develop indices of environmental vulnerability to oil (IEVO), by combining information about environmental sensibility to oil and results of numerical modeling of spilled oil. To achieve that, a case study concerning to oil spills scenarios in a subtropical coastal area was designed, and IEVOs were calculated and presented in maps, in order to make the information about the areas' vulnerability more easily visualized. For summer, the extension of coastline potentially affected by oil was approximately 150 km, and most of the coastline presented medium to high vulnerability. For winter, 230 km coastline would be affected, from which 75% were classified as medium to high vulnerability. Thus, IEVO maps allowed a rapid and clearer interpretation of the vulnerability of the mapped region, facilitating the planning process and the actions in response to an oil spill.

1. Introduction

Global maritime shipping has been steadily increasing over time, with a raise in the shipped volume from 8.4 billion tons in 2010 to nearly 9 billion tons in 2011 (UNCTAD, 2011). Regarding to the Brazilian coast, especially the south and southeastern regions, the growth of oil exploitation activity also contributes to a more intense traffic of support vessels and oil tankers, increasing the risk of oil spills related to accidents caused by collisions or groundings. This trend becomes more relevant in face of the recent discover of new oil fields in the deep-ocean layer known as pre-salt, and the beginning of exploitation of oil and gas located in that area.

Although the number of oil spills originated by oil tankers has declined significantly in recent years (Fingas, 2012), a single accident involving this type of vessel can generate catastrophic damage. One example is the spill caused by the accident involving the tanker Exxon Valdez in 1989, which released about 36,000 tons of crude oil in Alaska, affecting 1500 km of coastline (Van de Wiel and Van Dorp, 2011).

According to literature, small spills are usually related to operational failures, especially during loading and unloading and large spills are related to stranding and collisions (Poffo et al., 2001). On the other hand, large spills involving oil exploitation platforms may also occur, generating environmental impacts of great magnitude. On April 20th 2010, the explosion of Deepwater Horizon platform, in the Gulf of Mexico, released about 5 million barrels of oil in the sea (Ramseur, 2010). It is not possible to predict when these accidents may occur. Thus, oil spill response actions should be carefully planned, with the aim of reducing the impact caused by oil pollution in coastal and marine environments.

There are international conventions dealing with marine pollution such as the London Convention 72 (LC-72) and MARPOL, that emphasizes oil pollution (IMO, 2006). Emergency Response Division from National Oceanic and Atmospheric Administration (ERD/NOAA) supports emergency response activities for oil and hazardous chemical spills in coastal waters. Among all emergencies attended by ERD, the majority are oil spills. ERD develops tools to assist preparedness for response communities and NOAA provides standard techniques for observing oil, assessing shoreline impact, and evaluating and selecting cleanup technologies that have widely accepted by response agencies. Some of ERD's more widely distributed products are the Environmental Sensitivity (ESI) Maps, the trajectory forecasting tool GNOME and other models of analysis of dispersal chemicals. However, ESI Maps do not

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consider the probabilities of the spilled oil to reach coastal environments, but they have been worldwide used to estimate environmental vulnerability (NOAA, 2002), even without any information about oil dispersion modeling. International recommendations also mention to Maps of Environmental Vulnerability to Oil (MEVO) that should be drawn considering the probability that the oil will reach a given area, determined through simulations based on the worst case scenario of oil volume spill and by observation of previous oil spill incidents. No other information about the method for the preparation of vulnerability maps is described in this resolution.

Anyway, the different approaches have not been used as an integrated tool to establish priority areas in case of oil spills, and their separated use sometimes may be dubious or conflicting, especially if ESI maps and dispersion models do not agree in indicating priority areas to be protected from oil. Also, ESI maps have been used as they were MEVOs, very often ignoring results of oil dispersion models. Recently, the International Tanker Owners Pollution Federation Limited (ITOPF) released, on its webpage (www.itopf.com), a set of technical papers concerning to the problems related to oil spills, including contingency plans, but they still do not recommend integration of ESI maps and dispersion models.

MEVOs may be important planning tools for response actions after oil spill events, presenting information about the sensitivity and susceptibility of the mapped areas. Areas with high sensitivity and high probability of being affected by oil are considered more vulnerable than areas with low sensitivity and/or low probability of being affected. In this sense, the vulnerability maps should integrate information on environmental sensitivity to oil, obtained from the widest possible combination of environmental aspects, as geomorphological, chemical and physical characteristics and the biological, bathing, aesthetic and socio-economic responses (Castanedo et al., 2009; Mendonza-Cantú et al., 2011). In addition, MEVOs must consider the Maps of Environmental Sensitivity to Oil (ESI Maps), which present information about the sensitivity of a determined environment based on the type of coastline, biological resources and socioeconomic factors.

Gundlach and Hayes (1978) proposed the first method for classifying environments according to their sensitivity to oil. In their research, they established an index of environmental vulnerability to oil, based on the geomorphological characteristics of ecosystems. Since then, the terms sensitivity and vulnerability have been used interchangeably in many studies, although they may have different meanings. A discussion of the use of the terms vulnerability and sensitivity was presented by Silva et al. (2012). Environmental sensitivity is related to how the environment responds negatively to the impact of an oil spill (Silva et al., 2012). On the other hand, environmental vulnerability is determined by the environmental susceptibility to a certain impact, considering the structural weakness, sensitivity and maturity of the involved ecosystems. Environmental susceptibility to oil is the probability of a specific area of being reached and affected by oil, depending on climatic and oceanographic conditions, spill location, type and amount of spilled oil. .

Planning oil spill responses is a fundamental part of action to protect marine environments from pollution, because during real situations of environmental accident, the decision-making process is very difficult due to the lack of time and resources. Moreover, managers and/or stakeholders responsible for the oil spill response actions in the field are not often experts in environmental themes, evidencing thus the importance of developing a tool to support decision-making that includes environmental information, is easily understood (Ihaksi et al., 2011), and is effective in real situations.

This article aims to propose a method for producing maps of environmental vulnerability to oil, by the integration of information regarding to environmental sensitivity to oil and environmental susceptibility. To achieve that, a simulated case study will be presented.

2. Description of the studied area

To test the approach proposed in this study, we used the results of a numerical modeling of a hypothetical oil spill in the coastal region of the Santos Basin, located on the central-southern coast of São Paulo state (Brazil), which was previously described by Romero et al. (2011) (Fig. 1).

This segment of the coast is extensively dominated by sandy deposits, with predominance of well selected fine and very fine sands; also, coastal plains in this area present low declivity (Souza and Souza, 2004; Romero et al., 2010). Sandy beaches have low permeability to oil, but contain a large number of benthic species, mainly in the intertidal zone, and are frequently used as a feeding ground for many coastal birds (Borzone et al., 1996; Brazeiro, 2001; Defeo et al., 1992; Dexter, 1983; Fernandes and Soares-Gomes, 2006).

In general, the cities from studied area are highly urbanized; however, they are markedly by the lack of urban planning and constant population growth, which negatively affect the quality of life and causes ecological impacts. Towards South, urbanization tends to be less intense, as well as touristic activities. Anthropic structures give place to protected areas, covered by Atlantic rainforest and occupied by small traditional fishermen communities (Ramires and Barrela, 2003). Particularly in this region, protected areas represent biodiversity hotspots.

In the studied area, marine currents near the shore are strongly influenced by winds, flowing predominantly parallel to the coastline with alternating directions, depending on climatic conditions: from southwest to northeast during low pressure systems that move along the coast, and from northeast to southwest when high pressure stabilizes the weather (Picarelli et al., 2002). Thus, a spill occurring near the coast of the studied area could reach coastal environments and potentially spread along the coast. Simulations using numerical modeling for hypothetical spill point near-shore, in the Santos Basin, resulted in an oil slick that reached the coast (Romero et al., 2010).

3. Methodology

The approach used in the preparation of vulnerability maps integrates the use of ESI Maps, and also numerical modeling of oil slicks dispersion and transport. After the integration of these tools, the environment can be classified according to the environmental vulnerability index to oil, generating maps of environmental vulnerability to oil, as described below.

3.1. Maps of environmental sensitivity index (ESI Maps)

This study used ESI Maps previously prepared for the region by Romero et al. (2010), using the method proposed by the Ministry of Environment (MMA) (Brasil, 2004), which, in its turn, was originally proposed by NOAA (2002). Additionally, background information on the physical, biological and socio-economic aspects of the mapped area was reviewed.

Socio-economic traits relate to the activities of human use, occupancy, presence of fishing areas, farming, aquaculture, recreation, and archaeological and historic sites, among others. These aspects were gathered through a literature review and field campaigns, in which resource type and geographic location were determined. The characterization of the biological aspects was done from the review of the literature on species occurrence, as well as nesting, feeding and breeding sites. The physical aspects