The usefulness of ecotoxicological approaches to assess environmental impacts caused by oil spills

A utilidade de abordagens ecotoxicológicas para avaliar os impactos ambientais causados por derrames de petróleo

DOI:10.38152/bjtv6n1-005

Recebimento dos originais: 23/12/2022
Aceitação para publicação: 26/01/2023

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ABSTRACT
Accidents involving oil spills have a high potential to cause catastrophic environmental impacts. However, the Brazilian legislation and guidelines to plan and determine response actions in case of oil accidents are vague and generally do not include the assessment of toxic effects of oil on the exposed biota and ecosystems. Therefore, such actions are unable to adequately assess the environmental effects of oil in the short, medium and long terms. Ecotoxicological methods consist of cost-effective and robust alternatives to identify and quantify the effects of oil on the exposed ecosystems. Such approaches should be incorporated into response actions in episodes of oil spills in aquatic environments.

Keywords: oil spills, response actions, ecotoxicology, pollution.

RESUMO
Acidentes envolvendo vazamentos de óleo possuem alto potencial para causar impactos ambientais catastróficos. No entanto, as legislações e normas brasileiras orientando as ações de resposta em caso de acidentes com óleo são vagas e geralmente não contemplam medidas dos efeitos tóxicos do óleo sobre a biota e os ecossistemas, sendo assim incapazes de avaliar adequadamente os efeitos do óleo em curto, médio e longo prazos. A utilização de métodos ecotoxicológicos oferece uma alternativa custo-efetiva e robusta para identificar e quantificar os efeitos do óleo sobre os ecossistemas expostos, de modo que estas abordagens deveriam ser incorporadas às ações de resposta, nos episódios de vazamento de óleo em ambientes aquáticos.

Palavras-chave: vazamentos de óleo, ações de resposta, ecotoxicologia, poluição.

1 INTRODUCTION

The oil industry includes oil exploitation, transport, refining, and trade, which are widely considered potentially polluting activities. The expansion of oil exploration worldwide increases the maritime traffic with tankers and supporting ships and installation of oil platforms and pipelines, consequently increasing the risks of oil spills. Although the absolute numbers of oil spills has reduced over the last decades, a single accident can cause catastrophic damages, with severe ecological and socioeconomic impacts (Höfer, 1998; Huijer, 2005). For example, the accident involving the tanker Exxon Valdez, in 1989, released about 36,000 tons of crude oil in Alaska, affecting 1,500 km of coastline (Van de Wiel & Van Dorp, 2011). Generally, small spills are related with operational failures, while large oil spills frequently result of ship groundings and collisions, shipwrecks, ruptures of pipelines and storage tanks, and accidents in refineries (Poffo et al., 2001; Huijer, 2005).

According to the Information System on Chemical Emergencies of CETESB, the environmental agency of São Paulo (SIEQ – http://sistemasinter.cetesb.sp.gov.br), from 253 episodes reported to the state's coast, 57 (>25%) involved boat accidents with release of oil or its derivatives. These accidents were caused by mechanical failure, collision, shipwreck, or spill from the tanks, and the released volumes ranged from a few liters up to 6,000 tons. The SIEQ also mentioned the identification of 30 orphan oil spots, i.e. those without identified sources.

Large oil spills involving oil platforms commonly cause environmental impacts of great magnitude. In April 2010, the explosion of the Deepwater Horizon resulted in the spillage of about 5 million barrels of oil into the Gulf of Mexico (Ramseur, 2010). The Exxon Valdez and Deepwater Horizon cases represent clear examples of how problematic the accidents involving oil spill can become. In addition, it is impossible to predict when an accident involving oil spill will occur. Thus, response actions to such environmental emergencies should be carefully planned, with the purpose of minimizing the impacts caused by the oil in the coastal and marine environments. This paper aims at making a brief overview of the response actions in cases of oil spills on the Brazilian coast.

2 MATERIAL AND METHODS

The Brazilian legislation for marine and coastal oil spills were analyzed, as well as the national guidelines regarding response actions in case of oil spills, in order to identify how the impacts are considered and analyzed.

3 RESULTS AND DISCUSSION

In Brazil, there is a set of laws and guidelines for the planning of actions to combat the marine pollution by oil. The Federal Law 9.966 (Brasil, 2000) determines that "*organized ports, port facilities, and platforms, was well as their support facilities, must have individual emergency plans to combat the pollution by oil and other harmful substances*". Such plans need to be integrated with local and regional contingency plans, according to the Federal Decrees 4.871 (Brasil, 2003) and 8.127 (Brasil, 2013), which refer to the Area Plans and the Contingency National Plan (PNC) to incidents of oil pollution in waters of national jurisdiction, respectively. The Resolution 398 of CONAMA (Brasil, 2008) establishes that maps of environmental vulnerability to oil must be part of the individual emergency plans.

This set of legal tools is suitable and useful for planning and preparing the response actions in the case of oil spills, but when it comes to the assessment and monitoring the environmental impacts caused by oil, these guidelines are not clear. International guidelines are equally vague and only determine the need of assessing the chemical and biological aspects (IPIECA/IOGP, 2015; IMO/UNEP, 2009) without detailing how to do it, in terms of procedures to identify and quantify the impacts. Thus, the procedures for assessing the environmental impacts caused by the oil are frequently defined by the state or local authorities, being dependent of the authorities experience or expertise. In many cases, such assessments have included excessively simple actions that are incapable to quantify or properly assess the impacts on the affected environments. For example, during a major fire in a petrochemical terminal installed in the Port of Santos (SP, Brazil), the official impact assessment consisted mainly of monitoring the dissolved oxygen levels in the estuarine waters and grossly estimating the quantity of dead fish during the event, in spite of the large volumes of spilled fuels. An independent study including hydrodynamic modelling, chemical analyzes, and toxicity tests with effluent and field samples of water and sediments revealed severe and persisting effects, due to the chemical compounds spilled and those used to extinguish the fire (Abessa et al., 2017).

The environmental agencies and the national justice system have some difficulty to understand (and treat) the environmental impacts of oil spills in a realistic and deeper way. In an extensive study on the judicial actions involving oil spills, Silva (2019) noticed that, in such processes, the concept of environmental impact related with the oil is normally limited and focused on short-term impacts. In most cases, the impacts are associated with the visual detection of the oil in the environment, the visible death of fishes immediately after the event, and the economic demands of fishers and other stakeholders that rely directly on the affected natural resources. According to the author, chronic and long-term effects, as well as loss of species, or effects on the reproduction and restoration of fish stocks have not been considered in the environmental impact assessments, and consequently they are not included in judicial decisions. Therefore, the use of approaches to estimate, at least in part, the ecological effects at medium and long terms, is extremely necessary.

After the spill, the oil is subject to multiple processes, such as spreading, evaporation, dispersion, emulsification, dissolution, oxidation, siltation and biodegradation. The emulsification process generates the *mousse* (a combination of oil and entrapped water), increasing the volume of the pollutant. Due to its persistence in the environment, the *mousse* may carry the oil hydrocarbons for long distances (GESAMP, 1993). As a consequence of weathering and loss of mono-aromatic compounds, the polycyclic aromatic hydrocarbons (PAHs) become the main contributors for the toxicity of weathered oils (NRC, 2003).

The organisms from a site impacted by oil may be affected by two types of damages: those caused by body coverage by oil; and those due to intoxication after absorption of chemicals from the oil. In the majority of cases, the impacts are caused by a combination of both (Lopes et al., 1997; Hoff, 2002). Studies regarding mangroves impacted by oil showed that the oil can remain in the muddy substrate for long periods, and the toxicity persisted for 5 to 20 years after the oil spill (Burns et al., 1993, 1994). Late effects caused by an oil spill to a mangrove in Panama were verified 1.5 years after the accident, when mangrove trees died or were severely affected, in a site that was not immediately impacted after the oil spill (Hoff, 2002). Similar results were observed in Bertioga (SP, Brazil) after the rupture of an oil pipeline in 1983. In that case, the maximum impacts were identified 7 years after the spill (Rodrigues et al., 1990). The oil entrapped in the water column also may cause damages, as the oil droplets may be ingested by the zooplankton or incorporated in their fecal pellets (Lee et al., 1985; Concawe, 1998). High levels of toxicity, with mutagenic potential were reported in the water column of the Gulf of Mexico, 1.5 years after the explosion of the Deepwater Horizon platform (Paul et al., 2013). These examples highlight the need of long-term monitoring after an oil-spill.

In this context, the use of ecotoxicological approaches to assess the impacts of oil spills may provide useful and reliable information for a proper estimation of impacts, together with ecological studies conducted in field. In such cases, toxicity tests would consist of exposing selected organisms to the spilled oil (or its fractions or derivatives) and the determination of lethal and sub-lethal effects (Chapman & Long, 1983; Lamberson et al., 1992).

Water and sediment toxicity tests have been used in environmental impact assessment and programs of environmental monitoring, such as for disposal of dredged sediments and release of industrial and domestic effluents. They are simple, cost-effective, and can be performed with a range of species, producing a direct and integrated measurement of the effects resulting from the mixture of contaminants that normally occurs during an oil spill (Adams et al., 1992). For such reasons, toxicity tests have been recommended by the international environmental agencies, such as ASTM (1992), USEPA

(1998), and Environment Canada (1992) for environmental assessment and monitoring.

Fonseca et al. (2011) evaluated the impacts of a small-scale oil spill from a fishermen's boat that affected a beach at the Ilha Anchieta State Park, and detected marginal toxicity in sediment samples collected 2-3 days after the accident. Abessa et al. (2013) evaluated the toxicity of sediments collected at beaches of the São Sebastião Channel, which had been affected by an oil spill and then cleaned up manually by state and local authorities. Half of the samples exhibited toxicity, but authors stated that the remaining toxic compounds would be degraded by natural weathering. As previously mentioned, toxicity tests were successfully used to evaluate the impacts of the oil spill related with a major fire in the Port of Santos (Abessa et al. 2017). These examples show the usefulness of using toxicity tests to identify, quantify and monitor environmental impacts of oil spills. More recently, ecotoxicological approaches have been employed to assess the impacts of the mysterious oil spill that reached the coast of Brazil, mainly as part of academic independent initiatives.

4 CONCLUSION

Finally, as demonstrated above, ecotoxicological approaches should be included in the guidelines for responding to oil spill events, as standard tools for environmental assessment and monitoring. Such techniques should be routinely used to quantify the impacts, together with chemical analyzes and other biological approaches, in order to improve the quality of information available to decision-making. Moreover, such approaches should be used for long-term monitoring of the affected areas, providing reliable information for environmental management, response actions, and environmental policies.

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