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Evaluating the needs of risk assessment methods of potentially polluting shipwrecks

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ABSTRACT

Shipwrecks deteriorate and the probability of a release of oil increases with time on the sea floor. The potential leakage is a risk to the marine environment and may also have social and economic consequences. The purpose of this study was to evaluate existing methods for risk assessment of shipwrecks and suggest a generic risk assessment framework. A risk assessment is necessary for providing decision support on remediation actions and thus enabling an efficient use of available resources. Existing risk assessment methods aimed for assessing shipwrecks were evaluated by comparison to relevant parts of an international standard on risk management. The comparison showed that existing methods lack several key components of risk assessment procedures. None of the evaluated methods provide a comprehensive risk assessment for potentially polluting shipwrecks and few take into account uncertainty and sensitivity. Furthermore, there is a need to develop risk assessment methods considering long-term effects of continuous release of oil into the marine environment. Finally, a generic comprehensive framework for risk assessment of shipwrecks is suggested.

1. Introduction

Oil is released into the marine environment in a number of different ways, where natural seepage, shipping, coastal facilities and petroleum extraction are the most important sources contributing to the 1.3 million metric tons released every year (GESAMP, 2007; Farrington and McDowell, 2004). Leakage following ship collisions or groundings, operational discharges and leaking shipwrecks are all sources of petroleum pollution of the marine environment caused by shipping activities. During latter years there has been a growing concern about pollution from shipwrecks. Shipwreck deterioration is dependent on e.g. the time since wreckage, the type of vessel, construction, corrosion, biological factors, possible damage caused during sinking and powerful ocean currents. The probability of release of a significant amount of oil will thus increase with time (Monfils, 2005) and each wreck is unique in terms of potential of leakage and subsequent environmental impacts (Schmidt Etkin et al., 2009). According to an estimation by Michel et al. (2005), over 8500 wrecks (tank vessels ≥150 GT and non-tank vessels ≥400 GT) worldwide contain between 2.5 and 20.4 million metric tons of oil.

Oil released into the marine environment has different toxic effects on the biota, depending on the volume released, type of oil, resilience of the affected habitats, seasonality and availability of oil biodegrading microorganisms (Kingston, 2002). Large releases of oil often have acute lethal effects on both large and small scales due to the toxicity, physical fouling of larger fauna and hindering of UV/oxygen entering the water column (Jewett et al., 1999; Page et al., 2000; Rogowska and Namieśnik, 2010). Small, continuous releases of petroleum are known to have sublethal effects often caused by the most toxic components of oil, polycyclic aromatic hydrocarbons (PAHs) (Rawson et al., 2010). Consequences of these can be carcinogenic effects, changed taxonomical and ecological diversity in species communities and lowered fecundity (Hack et al., 2007; Lindgren et al., 2012; Rawson et al., 2010). However, there is still little known regarding how acute or chronic oil pollution affects functions of communities or ecosystems, even though toxic effects on individual organisms and changes in species composition in communities are rather well known (NRC, 2003).

Oil in shipwrecks represents a specific risk to the marine environment not only because of the potential environmental effect from the contained oil but also due to the uncertainty of probability

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and time of release. Shipwrecks are found in a wide range of locations, are deteriorating at varying rates and potential discharge will originate from the sea floor. Thus, a risk assessment method for wrecks must take into account the wreck-specific conditions.

Risks cannot be avoided, the option is rather to choose between them (Kaplan and Garrick, 1980). It is economically unfeasible and impractical to remediate all sunken shipwrecks, due to the large global number and remediation costs of 5–100 million USD per wreck (Schmidt Etkin et al., 2009). Hence, there is a need of prioritization of remedial actions and salvage operations of shipwrecks, to investigate where available resources can be used most efficiently to reduce the risks. It is preferable to take a proactive approach rather than a reactive since this will reduce the risk of negative environmental and socioeconomic consequences (NOAA, 2009). A proactive approach implies inspecting and performing corrective actions when needed prior to possible leakage and a reactive approach implies remediating affected areas after leakage of the shipwreck. Using a well-structured and transparent risk assessment approach to identify and prioritize shipwrecks that constitute the highest risk is fundamental in a proactive strategy. Adequate risk assessment concerning shipwrecks can help prioritize between remedial alternatives and provide necessary decision support.

Key questions before developing a relevant generic comprehensive risk assessment framework for shipwrecks are: What methods exist today for qualitative and quantitative risk assessments of the numerous wrecks in the oceans? Are these methods sufficiently comprehensive, from hazard identification to the modeling of an undesired spread of toxic substances and the effects on ecosystem functions?

1.1. Aims

The aim of this study was two-fold: (1) to compare and analyze identified current risk assessment methods for potentially polluting shipwrecks with respect to how these methods comply with relevant parts of an international standard for risk management, and (2) to suggest a generic framework for risk assessment of shipwrecks consisting of risk identification, risk analysis and risk evaluation.

2. The generic risk management framework

The framework presented by ISO (2009) describes a well-established view of the risk management process that is applied in many different fields such as engineering, traffic safety, medicine, and drinking water production. Similar frameworks have been presented by e.g. AZ/NZS (2004a, 2004b), IEC (1995) and the Swedish Civil Contingencies Agency (2003).

The general process of risk management consists of a number of steps (Fig. 1). Initially it involves an establishment of the context where the scope and goal of the risk management work is stated. This is followed by the risk assessment where risk identification is performed which implies identification of areas of impact, events, sources of risks and potential causes and consequences. Risk assessment also involves a risk analysis process to develop an understanding of the risk and to provide input to the subsequent risk evaluation. The risk analysis comprises of qualitative, semi-qualitative or quantitative estimations of risk levels. An evaluation of what risks to consider and how to prioritize among them is included in the risk evaluation step, together with a comparison of possible alternatives to mitigate the risks. This provides support to the decision-makers on benefits and limitations of possible risk treatment alternatives (ISO, 2009).

Subsequently, unacceptable risks should be treated using the alternative measures identified as most suitable. Communication and consultation with stakeholders need to take place throughout the entire process to ensure that those responsible for making decisions regarding the implementation of the risk management process understand concepts and results of performed risk assessment. Furthermore, monitoring and review should be performed throughout the risk management process to detect changes affecting the risk criteria and/or the actual risk, to identify emerging risks and to ensure that mitigation measures are effective (ISO, 2009).

There are also separate and more specific guidelines concerning environmental impact which are more detailed with respect to effects, such as the Guidelines for Ecological Risk Assessment (USERA) by the U.S. EPA (1998). USERA is a framework mainly comprised of problem formulation, analysis and risk characterization which are preceded by a planning process. In the problem formulation the purpose is declared, the problem defined and an analysis plan set out. The phase of analysis is further compiled of a characterization of exposure and a characterization of ecological effects. Moreover, the risk characterization contains an estimation and description of the risk.

The purpose of risk analysis as suggested by Aven (2003) is to support decision-makers in making good decisions, rather than to produce numbers. The description of risk analysis by Aven (2003) is clearly linked to the ISO description of risk assessment (ISO, 2009). Decisions on, for example, remedial actions have to be made although the final outcome is unknown. Thus, decisions need to be made under uncertainty and Aven (2003) suggests a basic structure for the decision-making process from stating goals, criteria and preferences to the final decision (Fig. 2). The decision-making is thereby embedded in a framework wherein the risk analysis is a tool to provide input to the decision process.

Decision-making can thus be seen as a process supported by formal risk and decision analyses in combination with managerial judgment and review (Aven, 2003). Risk assessment and decision-making are closely linked and this should be considered when developing methods for risk analysis and risk assessment in general.

3. Current approaches for risk assessment on shipwrecks

Scientific papers, official governmental documents and official reports were reviewed and the identified risk assessment methods were compared to the ISO framework for risk assessment. Well-known material, as the Nairobi International Convention on the Removal of Wrecks (IMO, 2007) was not intended as such framework and the IMO Guidelines for Formal Safety Assessment (FSA) for use in the IMO rule-making process (IMO, 2002) is not a wreck specific guideline. Moreover the Pre-study on Shipwreck Assessment and Remediation by Hassellöv (2007) was not intended as a full guideline or method for risk assessment of shipwrecks and is therefore not included in this study.

We here refer to the term *method* when comparing the identified approaches even though the level of detail varies. In total, six methods for assessing risks to the environment posed by shipwrecks were identified. An overview of each method is presented below. Each of the six methods identified is assigned a letter from A to F to facilitate the subsequent comparison.

A. The Wreck Oil Removal Program (WORP) presented by the National Oceanic and Atmospheric Administration NOAA as a demonstration project overview, aims to use a scientifically-based approach to oil removal and intends to minimize costs and risk of pollution from sunken commercial vessels (NOAA, 2009).
B. Michel et al. (2005) in “Potentially polluting wrecks in marine waters” present a guide for assessing oil release from potentially polluting shipwrecks with regard to consequences and risk. The goals of the report are to objectively analyze shipwrecks with