



Assessment and Selection of an Appropriate Oil Spill Response Method in Gulf of Oman

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Article Info	ABSTRACT
Article type: Research Article	The Gulf of Oman is one of the most important marine areas in southern Iran, with considerable economic and environmental significance due to its fisheries resources, maritime transportation capacities, trade, and tourism potential. However, extensive vessel traffic, particularly by commercial vessels and oil tankers, increases the risk of oil pollution and its associated consequences. Oil spills and petroleum products can have extensive adverse effects on marine ecosystems, coastal areas, aquatic organisms, fisheries, and tourism activities. Therefore, selecting an appropriate and effective method for responding to oil spills, considering the environmental conditions of the region, is of particular importance. The aim of this study was to determine and prioritize the most appropriate method for responding to oil spills in the Gulf of Oman using the Analytic Hierarchy Process based on the physical characteristics of seawater. In this study, six criteria, including temperature, salinity, turbidity, water-current velocity, depth, and dissolved oxygen, were considered as decision-making criteria. First, a pairwise comparison matrix was constructed to determine the relative importance of the criteria and calculate their weights. The consistency of the pairwise comparisons was also evaluated using the Consistency Ratio. Subsequently, based on the criterion with the highest relative weight, different oil-spill response methods were compared and prioritized according to the selected criterion. The results showed that temperature, with a weight of 0.40, had the highest relative importance among the criteria considered. The Consistency Ratio of the pairwise comparison matrix was 0.0416, indicating an acceptable level of consistency. Furthermore, based on temperature as the dominant criterion, adsorption, with a weight of 0.354, ranked first among the oil-spill response methods, followed by chemical dispersants (0.271), mechanical methods (0.209), in situ burning (0.113), and bioremediation (0.057). The findings indicate that the Analytic Hierarchy Process can provide a systematic framework for weighting environmental criteria and prioritizing oil-spill response methods in the Gulf of Oman.
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Introduction

The coastal zone of the Gulf of Oman, extending from Gwadar Bay to the eastern shores of Bandar Abbas, is an ecologically and economically important marine region that supports fisheries, maritime transportation, trade, tourism, and other marine-based activities. Intensive maritime traffic, particularly the movement of commercial vessels and oil tankers, increases the risk of oil spills and their associated environmental and economic consequences. Oil pollution can adversely affect marine ecosystems, coastal areas, aquatic organisms, fisheries, and tourism activities. Therefore, selecting an appropriate response method that is compatible with the environmental conditions of the study area is essential for effective oil-spill management.

Various methods have been developed to respond to oil spills, including mechanical recovery, in-situ burning, chemical dispersants, bioremediation, and adsorption. The effectiveness of these methods can vary depending on environmental conditions and the characteristics of the spilled oil. Consequently, selecting an appropriate response method is a multi-criteria decision-making problem that requires systematic evaluation of relevant environmental parameters. The Analytic Hierarchy Process (AHP) is a widely used multi-criteria decision-making technique that enables the relative importance of decision criteria and alternatives to be determined through pairwise comparisons. Accordingly, the present study aimed to determine and prioritize an appropriate oil-spill response method for the Gulf of Oman using AHP and considering the physical characteristics of seawater. Six physical parameters, including temperature, salinity, turbidity, current velocity, water depth, and dissolved oxygen, were considered as decision-making criteria. The study further sought to identify the criterion with the highest relative importance and subsequently prioritize available oil-spill response methods based on that criterion.

Method

A multi-criteria decision-making framework based on the Analytic Hierarchy Process (AHP) was employed. First, a pairwise comparison matrix was developed for six physical seawater parameters, including temperature, salinity, turbidity, current velocity, depth, and dissolved oxygen. Pairwise comparisons were performed using the fundamental AHP scale from 1 to 9. The relative weight of each criterion was then calculated based on the pairwise comparison matrix. To assess the consistency of the judgments, the Consistency Ratio (CR) was calculated using the Consistency Index (CI) and Random Index (RI). The obtained CR value was also used to determine whether the pairwise comparisons had an acceptable level of consistency.

After identifying the criterion with the highest relative weight, a second pairwise comparison was conducted among five oil-spill response methods, including adsorption, chemical dispersants, mechanical recovery, in-situ burning, and bioremediation. Importantly, the ranking of these response methods was performed based on the dominant criterion identified in the first stage, rather than through an integrated weighting of all six physical parameters. Thus, the second stage of the analysis was specifically designed to determine the priority of response methods under the dominant environmental criterion identified by the AHP framework.

Results

The AHP results showed that temperature had the highest relative weight among the six physical seawater parameters, with a weight of 0.40, followed by salinity (0.25), turbidity (0.15), current velocity (0.08), depth (0.07), and dissolved oxygen (0.05). The Consistency Ratio of the pairwise comparison matrix was calculated as 0.0416, which is below the commonly accepted threshold of 0.10 and indicates an acceptable level of consistency in the pairwise judgments. Although the Gulf of Oman is not necessarily among the warmest marine regions, the relatively high weight assigned to temperature in this study does not indicate that the region has the highest absolute seawater temperature. Rather, the weight represents the relative importance of temperature within the decision-making structure of the present AHP

model. Temperature can influence several processes relevant to the fate and behavior of oil spills, including changes in oil viscosity and evaporation of volatile components. It may also affect the performance of certain oil-spill response methods and biological processes involved in hydrocarbon degradation. Therefore, the relatively high weight of temperature can be interpreted in terms of its potential influence on oil-spill behavior and response effectiveness rather than simply its absolute value. Based on temperature as the dominant criterion, adsorption obtained the highest priority among the evaluated response methods, with a weight of 0.354. Chemical dispersants ranked second (0.271), followed by mechanical recovery (0.209), in-situ burning (0.113), and bioremediation (0.057). Thus, within the decision-making structure of this study and specifically under the temperature criterion, adsorption was identified as the highest-priority response method. The results indicate that the ranking presented in this study should be interpreted within the defined AHP framework. In particular, the ranking of response methods reflects their priority according to the dominant criterion identified in the first stage and does not represent an overall ranking obtained by simultaneously aggregating all six physical seawater criteria.

Conclusions

The present study employed the Analytic Hierarchy Process (AHP) to systematically evaluate the relative importance of physical seawater parameters and prioritize oil-spill response methods in the Gulf of Oman. Among the six physical parameters considered, temperature received the highest relative weight (0.40), indicating its dominant position within the decision-making structure of the study. The Consistency Ratio (CR = 0.0416) confirmed the acceptable consistency of the pairwise comparisons. Based on the dominant temperature criterion, adsorption achieved the highest priority (0.354) among the evaluated oil-spill response methods, followed by chemical dispersants, mechanical recovery, in-situ burning, and bioremediation. The results suggest that adsorption can be considered a high-priority response option under the decision conditions defined in this study. However, this finding should not be interpreted as a universal superiority of adsorption over other response methods, since the ranking was derived specifically from the dominant temperature criterion identified through the AHP procedure. Overall, the findings demonstrate that AHP can provide a systematic framework for incorporating environmental considerations into oil-spill response decision-making. The proposed approach can assist environmental managers in prioritizing response options under specific environmental conditions in the Gulf of Oman. Future studies may improve the framework by incorporating additional environmental and operational criteria, performing sensitivity analysis, and validating the AHP results using field observations and real oil-spill response data.

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