APPROACHES AND APPLICATION OF COMPARATIVE RISK ASSESSMENT CONCEPTS TO OIL SPILL PREPAREDNESS PLANNING AND RESPONSE

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ABSTRACT: *Comparative Risk Assessment (CRA) is emerging as a methodology that may be applied to facilitate decision-making when various possible activities compete for limited resources. The CRA framework may be an especially valuable tool for prioritization of remediation efforts and for making choices among various environmental policies specific to oil industry operations. This paper will show that CRA is an efficient and cost-saving tool that assists in developing oil spill response priorities based on the broadest possible range of concerns and issues important to all stakeholders. In addition, the CRA approach allows the cost/benefit evaluation of alternative environmental policies and strategies relative to the baseline risks and disruptions associated with oil spills (as well as other costs and benefits of petroleum use).*

Introduction

Oil spills create both acute and chronic disturbances in coastal and estuarine areas. Even though mechanical countermeasures are still used extensively to remove and recover oil products, experience shows that recovery rarely retrieves more than 10-20% of the spilled oil. The low efficiency of mechanical oil removal techniques, coupled with their inability to provide the desired level of environmental protection, has resulted in the development of other response countermeasures and technologies (*in situ* burning, chemical dispersion, etc.) and their regulatory acceptance in many regions. The effective and timely selection of the optimal response strategy plays a crucial role in a successful response to a specific oil spill.

Recognizing the need for improved oil spill response, NOAA and other agencies have recently developed protocols and selection guides for the selection of optimal technologies (NOAA, 2000, SAA, 2000, Aurand et al., 2000, SMART, 2001). These guidance documents focus on the technical efficiency of alternative techniques as well as empirical observations and experiences from past releases to address imminent hazards to public health and the environment. Although these methods provide valuable insights into the procedure of response alternative selection, this approach may be not optimal for the protection of habitats, ecosystems, and public health concerns specific to the release site, because ecological and human health risks are not explicitly incorporated into the decision process.

Risk assessment methodology

The purpose of risk assessment is to evaluate the extent of the influence of environmental contamination and physical disturbances on humans and biota; and then, coupled with the use of risk management objectives, to guide environmental decisions so as to minimize risk to receptors while maximizing economic and social benefits. Significant uncertainty surrounds both the risk evaluation of environmental conditions and the resulting estimates of ecological and health-related post-remediation benefits. To make policy decisions under such uncertainty, a framework in which similar metrics are used to rank different alternatives is needed. Comparative Risk Assessment (CRA) is a methodology applied to facilitate decision-making, especially when various activities or risk management options compete for limited resources. The application of this methodology is flexible. In the case of oil spills, various response options can be prioritized and ranked according to the nature and severity of environmental risk associated with each.

Risk-based approaches are increasingly being used in remedial action planning. Ecological and human health risk assessment are widely used at Superfund sites. The Federal Emergency Management Association (FEMA) has recently proposed making risk assessment the foundation for its natural hazard mitigation planning process. The U.S. Coast Guard (USCG) has recently developed the first regulatory guidance that uses the risk assessment approach to guide environmental protection in oil spill response planning (Aurand et al., 2000). This approach has been tried at several sites, including the Galveston Bay area and the San Francisco Bay area (Pond et al., 2000a/b).

This paper conceptualizes a formal protocol, based on risk assessment, that could guide decision-making for environmentally sound oil spill response actions, as well as the long-term management of affected coastal and estuarine ecosystems. Building on the USCG oil spill response guidance mentioned above, this systematic evaluation procedure could be developed and implemented as a user-friendly software package

that would guide policy decisions regarding which areas and habitats should have the highest priority for protection and which remedial methods should be implemented.

Design and application of risk-based protocols in oil spills response

Although risk assessment is widely used, the application of risk assessment (especially ecological risk assessment) methodology to oil spills has not been standardized. The compilation of resource databases by NOAA and other agencies provides a unique and timely opportunity for building a computer-based decision-making framework based on CRA. For example, under the Oil Pollution Act of 1990, NOAA is developing Environmental Sensitivity Index (ESI) maps that will be used as assessment endpoints in ecological risk assessment. The conceptual models developed for generic oil spills could depict the movement of contamination from the spill to affected habitats. Oil spill modeling software developed by NOAA (GNOME, ADIOS, TAP, etc.) and other agencies could be dynamically linked to ESI endpoints by using the risk assessment framework. Integral to this effort is incorporation of information related to the efficiency of dispersants and other alternative response methods, as well as their relative costs.

Sizeable research has focused on the toxicity of oil products, ecological consequences of oil spills, and remedial options. Largely missing, however, is a comprehensive array of effective ecological assessment and management tools that relate the type, magnitude, and timing of the oil spill and the impact of disturbances on critical physical, biological, and chemical thresholds for sustaining ecosystem functions. Rather, the focus has been on capturing the potential for environmental impacts based on single-species toxicity data. The tools and protocols to be developed for ecological CRA must serve the dual purpose of assuring optimal site remediation and the restoration of ecological sustainability, while avoiding the constraint of limiting considerations to only a single or few specific response actions or strategies. Incorporation of CRA into rigorous decision protocols will allow the comparison of different remedial alternatives and the selection of approaches that are optimally suited for site-specific applications.

The CRA approach would integrate a number of risk and habitat assessment techniques into a systematic protocol for assessing and managing natural ecosystems at specific sites of interest of environmental resource managers. The following categories of the quantitative risk assessment would need to be formalized and implemented as part of risk-based protocols for such a project:

- Site characterization and problem formulation
- Environmental fate and transport modeling
- Exposure dose and response/effects computer modeling.

By integrating proven methods and principles regarding ecological impact, risk assessment and habitat evaluation and restoration, the protocol could help managers develop creative solutions to the problem of cumulative stresses to the ecosystem from continuing and past environmental stresses, including oil spills.

Future steps

The main goal of risk-based protocols is to select the oil spill response alternatives that minimize overall ecological risks for a given situation. The methodology also provides a general framework that allows the development of performance standards and criteria that will increase the industry's ability to respond to oil spills in a cost-effective manner and meet regulatory expectations for environmental protection.

We are currently working on implementing a risk-based framework for evaluation of oil spill response alternatives encapsulated in a user-friendly software package. The framework is built on the available tested and widely applied protocols for oil spill response and recent developments in comparative risk assessment methods. It will then be developed as a prototype software "tool kit" from which decision-makers can select the most appropriate alternatives for each specific spill. Each option will be examined for its potential to both mitigate and aggravate the environmental harm from an oil spill. The software prototype will compare alternatives based on established criteria of oil encounter rates and removal efficiency, response time, spatial and temporal extent of habitat oiling, resulting environmental exposures and ecological risks. This side-by-side comparison among response options will become a foundation for ranking response strategies. Decision-makers should be able to tailor the software to address specific spill characteristics and local environmental conditions. The software and tools will support the development of contingency plans, assessment activities, and restoration efforts following oil spills.

Implementation of risk-based protocols in different countries

Overcoming critical obstacles posed by inexperienced regulatory institutions and limited technical and analytical resources in developing countries is critical to successful implementation of risk-based protocols on a broader scale. This issue was specifically addressed at the NATO Advanced Research Workshop, which took place in Lisbon, Portugal in October, 2000 (Linkov and Oliveira, 2002). General agreement was reached that risks associated with environmental problems should be considered in the development of environmental policies, while the application of the specific methodologies (such as CRA and probabilistic techniques) should be site-specific and consider cost-benefit factors. The workshop presentations and group discussions developed a unified consensus among participants as to the importance of flexibility, adaptability, practicality, and partnering in applying environmental risk assessment in developing countries.

Country-specific regulations and political environments could produce differences in risk assessment protocols and interpretation of risk assessment results. There are a number of recent global regulatory and legal trends that have come to the forefront of the management of environmental problems in different countries. In many countries, the risk assessment process uses basic scientific information to evaluate potential risks to human health and the environment. Typically, these evaluations are then used to determine if remedial action or cleanup is necessary and if so, how much is needed; thus, they may also be used to determine goals for site restoration.

Given that the United States (U.S.) has developed extensive risk assessment guidance—for example, human health and ecological risk assessment guidance for Superfund sites, and numerous policies regarding the use of risk assessment in environmental problem solving—it is not surprising that methodologies in many other countries are similar. New laws and guidelines regarding risk assessment are being developed and

implemented across Europe. Common European Union (E.U.) regulations have not been yet developed; rather, the focus is on individual regulations for each country. Countries such as Italy and Netherlands have developed specific risk-based benchmarks for contaminant concentration in different media, whereas others such as the United Kingdom have adopted general guidelines instead. However, for many countries, including the U.S., there are many issues surrounding the science of risk assessment that are as yet unresolved. These issues include the following: 1) existence of uncertainties inherent in the risk assessment process; 2) relative importance of human health versus ecological risk; 3) what constitutes acceptable or unacceptable levels of risk for human and ecological receptors; and 4) the role of risk communication (i.e., consensus among all stakeholders).

Conclusion and future development

The intent of this paper is to increase awareness regarding the potential for incorporation of CRA into decision-making relating to oil spill response. Further development of the risk-based approaches and protocol will:

- Further develop risk assessment algorithms;
- Make direct use of geographic information systems (GIS) technology, and further integrate data with GIS;
- Develop database with profiles for a wide range of ecological receptors and habitats; using what sources of information?
- Develop database of exposure parameters and risk benchmarks;
- Expand functional modeling capabilities to include food chains and other dynamic factors of the specific ecological situation; and
- Link the user to expert decision support systems.

We are implementing this framework in a dynamic software package. This software package will become integral to contingency planning, as well as in selecting the best response to an incident, given specific spill characteristics and meteorological conditions.

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