

การกำกับติดตามการบังคับใช้กฎหมายสิ่งแวดล้อมทางทะเล
กรณีน้ำมันรั่วไหลจากเรือเดินสมุทรในท่าเรือหลักของไทย
Oil Spill Monitoring and Marine Environmental Law Enforcement for
Ship-Source Pollution in Major Ports of Thailand

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บทคัดย่อ

การรั่วไหลของน้ำมันจากเรือยังคงเป็นปัญหาสิ่งแวดล้อมที่สำคัญในท่าเรือขนาดใหญ่ โดยเฉพาะในประเทศที่กำลังพัฒนาศักยภาพทางทะเล งานวิจัยนี้ศึกษาการติดตามกำกับดูแลการบังคับใช้กฎหมายกรณีน้ำมันรั่วไหลในท่าเรือหลักของไทย ท่าเรือมาบตาพุด ท่าเรือสัตหีบ และท่าเรือแหลมฉบัง เน้นความสัมพันธ์ระหว่างการบังคับใช้กฎหมายกับการนำเทคโนโลยีสมัยใหม่มาใช้ในการบูรณาการปฏิบัติงานและประสิทธิภาพของการปฏิบัติการ ใช้ระเบียบวิธีวิจัยแบบผสมผสาน ขั้นที่ 1 เก็บข้อมูลเชิงคุณภาพผ่านการสัมภาษณ์เชิงลึกแบบกึ่งโครงสร้างจากผู้เชี่ยวชาญและผู้บริหารหน่วยงานที่มีส่วนได้เสียแบบเฉพาะเจาะจง 11 ท่าน พบว่าการใช้เทคโนโลยีสมัยใหม่ เช่น ดาวเทียม ยานไร้คนขับ และปัญญาประดิษฐ์ รวมทั้งการจัดการข้อมูลดิจิทัลและการบูรณาการระบบเฝ้าระวังแบบเรียลไทม์ มีผลต่อการติดตามกำกับดูแลการบังคับใช้กฎหมาย ในขั้นที่ 2 ทำการประเมินเชิงปริมาณในการรับรู้ประสิทธิภาพการกำกับดูแลกรณีน้ำมันรั่วไหลจากกลุ่มตัวอย่างในขั้นที่ 1 วิเคราะห์ข้อมูลโดยใช้สถิติเชิงพรรณนา พบว่ากลไกการเฝ้าระวังและตอบสนองน้ำมันรั่วไหลต่ออุบัติเหตุการเดินเรือได้รับการประเมินว่ามีประสิทธิภาพในระดับสูง แต่มีประสิทธิผลลดลงในกรณีข้อขัดข้องทางเทคนิคและความผิดพลาดจากผู้ปฏิบัติงาน และมีระดับต่ำในกรณีการสอบสวนและการดำเนินคดี การศึกษาชี้ให้เห็นว่าเทคโนโลยีตรวจจับและติดตามสมัยใหม่และการจัดการข้อมูลดิจิทัลเป็นปัจจัยสำคัญต่อการบรรลุเจตนารมณ์ของกฎหมาย ดังนั้น จึงต้องพัฒนานโยบายพร้อมแนวทางบูรณาการกับการขับเคลื่อนด้วยเทคโนโลยีสมัยใหม่และการใช้ข้อมูลดิจิทัลทางกฎหมายตามมาตรฐานสากล ตลอดจนเสริมสร้างสมรรถาภิบาลและการพัฒนาทางทะเลอย่างยั่งยืน

คำสำคัญ: น้ำมันรั่วไหลจากเรือเดินสมุทร, ประสิทธิภาพการบังคับใช้กฎหมาย, เทคโนโลยีการติดตาม, การจัดการท่าเรือ

Abstract

Ship-source oil spills remain a persistent environmental challenge in large ports, particularly in developing maritime states. This study investigates oil spill monitoring and law enforcement in Thailand's major ports, including Map Ta Phut, Laem Chabang, and Sattahip, with a focus on the interaction among technology, data, institutional coordination, and enforcement. It employs a mixed-methods research design (n = 11), combining qualitative interviews and quantitative expert elicitation. In Phase 1, qualitative data were collected through semi-structured in-depth interviews with eleven purposively selected key stakeholders and analyzed thematically to identify structural, technological, and legal constraints. The findings indicate that advanced monitoring technologies, including satellite-based surveillance, unmanned aerial vehicles (UAVs), real-time sensing systems, AI-based data analytics, digital data management systems, and integrated real-time monitoring platforms, are critical for effective detection and response. In Phase 2, quantitative assessments were conducted with the same group using a five-point Likert scale to evaluate

perceived government effectiveness. The findings reveal a clear disparity in enforcement effectiveness across different types of oil spill incidents. Monitoring and response mechanisms for navigation-related accidents were perceived as highly effective (mean = 4.00-4.27). In contrast, effectiveness declined to moderate levels for incidents caused by technical failures and human error (mean = 3.00-3.27). It was rated low for the investigation and prosecution of illegal oil discharges (mean = 2.73). The results highlight a significant enforcement gap between law enforcement practices and the adoption of advanced monitoring technologies, as well as their impact on operational effectiveness, primarily due to limitations in legal frameworks, evidentiary standards, and inter-agency coordination. The study underscores the need to develop integrated policies to enhance technological integration, recognize digital data as admissible legal evidence, and strengthen institutional coordination to meet international standards, thereby improving maritime good governance and sustainable marine development.

Keywords: Ship-source oil spills, Law enforcement effectiveness, Monitoring technology, Port governance

1. Introduction

Marine oil pollution from ships continues to pose significant environmental and governance concerns, particularly in large commercial and industrial ports where maritime traffic and oil-related activities are highly concentrated. Oil spill incidents in such areas can cause significant ecological damage, disrupt port operations, and undermine public confidence in environmental regulation (Ebisi et al., 2025). Effective management of ship-source oil pollution, therefore, requires not only a comprehensive legal framework but also robust institutional capacity and operational mechanisms that enable prevention, detection, and enforcement in practice (Siraphum & Nannapasorn, 2021).

At the international level, marine oil pollution is governed by well-established legal instruments, including the United Nations Convention on the Law of the Sea (UNCLOS), the International Convention for the Prevention of Pollution from Ships (MARPOL), and the International Convention on Civil Liability for Oil Pollution Damage (CLC) (Hadavand et al., 2022; Jumphot, 2017; Department of Legal Treaties, 2005; Subcommittee on Knowledge Management for National Maritime Interest, 2019). These instruments establish obligations related to pollution prevention, monitoring, reporting, and liability. However, existing literature suggests that the primary challenge lies not in the absence of legal frameworks, but in the effective implementation and enforcement of pollution control regimes at the operational level. Previous studies further indicate that ship-source oil spill incidents arise from multiple causes, including maritime accidents, technical and design failures, human error, and intentional illegal discharges. These causes are closely linked to broader systemic issues, including policy clarity, legal adaptation, inter-agency coordination, data integration, and gaps in operational and personnel standards (Purohit et al., 2024).

In light of these findings, in large port contexts, oil spill governance is shaped by the interaction of multiple authorities responsible for environmental protection, maritime safety, and maritime security. Fragmented mandates, limited inter-agency coordination, and uneven access to operational data have been widely identified as factors that weaken enforcement outcomes, particularly in cases involving operational failures or covert non-compliant practices. These challenges are further compounded when incidents involve foreign-flagged vessels, giving rise to jurisdictional and evidentiary constraints that complicate investigation and prosecution processes (Siraphum & Nannapasorn, 2022).

A recent study highlights the growing role of advanced monitoring and surveillance technologies in enhancing oil spill detection and enforcement capacity. Such technologies include sensing systems,

unmanned vehicles, mathematical and trajectory models, artificial intelligence and data analytics, communication networks, and environmental data integration platforms (Siraphum et al., 2025). Beyond their technical functions, these technologies increasingly serve as institutional enablers by linking regulatory intent to enforcement outcomes through improved situational awareness, coordinated responses, and evidentiary support for investigation and prosecution. Nevertheless, limitations persist in inter-agency data integration and in the absence of clear legal mechanisms to support the admissibility of technological evidence in judicial processes. Empirical research examining how these technologies are operationalized within legal enforcement practices at the port level remains limited, particularly in developing maritime states (Al-Qassim, 2023).

In Thailand, major ports such as Map Ta Phut, Laem Chabang, and Sattahip play a critical role in international trade and industrial development; however, increasing maritime traffic and energy-related activities (Marine Department, 2024), particularly within the Eastern Economic Corridor, pose a significant risk of ship-source oil pollution (Marine Department, 2021). Although Thailand has ratified relevant international instruments governing ship-source oil pollution, limitations persist in operational enforcement and preventive capacity at the port level. At the domestic level, an extensive legal framework has been enacted to support the implementation of these international obligations (Govindarajan et al., 2021). Key legislation includes the Enhancement and Conservation of National Environmental Quality Act, the Promotion of Marine and Coastal Resources Management Act, and the Thai Navigation in Thai Waters Act, as well as related maritime liability and compensation laws. However, the enforcement of these laws is distributed across multiple government agencies with overlapping mandates, resulting in challenges related to coordinated operations, data sharing, and consistent enforcement practices (De Kerf et al., 2024).

Although previous studies have identified constraints related to monitoring capacity, institutional coordination, and enforcement effectiveness in ship-source oil pollution governance, existing literature remains largely descriptive, with limited integration of technological, institutional, and legal dimensions, particularly in developing maritime states. Consequently, there is limited empirical understanding of how existing legal and institutional frameworks function in practice at the operational level within major port environments. In this study, effectiveness is operationally defined as the perceived performance of monitoring and enforcement systems across operational stages, including prevention, emergency response, investigation, and prosecution, based on expert Likert-scale assessments and qualitative insights. This study addresses these gaps by examining stakeholder perspectives on the effectiveness of oil spill monitoring systems, legal enforcement, and institutional coordination in Thailand's major ports, including Map Ta Phut, Laem Chabang, and Sattahip, using a mixed-methods approach that integrates qualitative interviews with quantitative assessments of enforcement effectiveness.

The study addresses the following research questions: 1) How effective are current monitoring and law enforcement mechanisms across operational stages? and 2) What technological and institutional factors influence enforcement effectiveness? It also identifies key technological, institutional, and legal factors shaping ship-source oil spill governance and provides policy-relevant insights for strengthening technology-enabled enforcement and sustainable port management.

2. Materials and methods

This study employed a mixed-methods research design comprising two successive stages: (1) a qualitative stage aimed at exploring key challenges in oil spill monitoring, law enforcement, and institutional coordination, and (2) a quantitative stage designed as an expert elicitation approach to assess the perceived

effectiveness of monitoring and law enforcement. The study framework is informed by a socio-technical perspective, conceptualizing oil spill governance as an interaction among monitoring technology, institutional capacity, and legal enforcement. These three dimensions are analytically framed as interdependent components, where technological capabilities enable detection and monitoring, institutional capacity determines coordination and implementation effectiveness, and legal enforcement provides the regulatory authority for compliance and accountability.

While previous studies have examined these dimensions in isolation, this study contributes by integrating them into a unified socio-technical framework. Furthermore, the expert elicitation approach provides empirical evidence from real-world experience on how the interactions among these factors affect the effectiveness of monitoring and law enforcement in the context of maritime governance. In-depth interviews were conducted with experts from a range of stakeholder groups involved in maritime operations and environmental law enforcement in Thailand. This design enabled the collection of detailed qualitative insights into key challenges, alongside structured quantitative data on stakeholders' assessments of the effectiveness of existing monitoring and enforcement systems. This study was approved by the Institutional Review Board (IRB) of Ramkhamhaeng University, RU-HRE 67/0086, 17 May 2024. Informed consent was obtained from all participants.

2.1 Data Collection

In Phase 1, qualitative data were collected through semi-structured in-depth interviews with 11 purposively selected key informants who had direct responsibilities for, or professional expertise in, the monitoring, regulation, and response to marine oil pollution incidents in Thailand. The informants represented a broad range of institutional perspectives and included academics and senior officials from relevant organizations, namely the Map Ta Phut Industrial Port Office, 1 person; Sattahip Commercial Port, 1 person; the Operations Office of the Marine Department, 1 person; the Thai Maritime Enforcement Command Center (TH-MECC), 2 persons; the Marine Police, 1 person; the Judge Advocate General's Office, 1 person; HTMS Similan, 1 person; the Investigation and Legal Office of TH-MECC, 1 person; the Meteorological Department, 1 person; and the Faculty of Logistics (Maritime Business), Burapha University, 1 person.

The interviews followed a semi-structured format, using predefined guiding questions aligned with the research objectives while allowing flexibility for open discussion and follow-up probing based on the informants' expertise and responses. This approach enabled the collection of detailed, context-specific insights into practical challenges related to oil spill monitoring, legal enforcement, and institutional coordination. The interviews focused on three primary issues: (1) challenges in law enforcement under domestic and international legal frameworks; (2) the role and adequacy of existing technologies for monitoring and enforcement; and (3) the effectiveness of current preventive measures addressing different causes of oil spill incidents. The research instrument consisted of two components: an introductory component collecting general background information from the informants, and a substantive component comprising questions organized into five thematic areas. These areas addressed: (1) limitations in the enforcement of marine environmental laws at national and international levels, particularly in cases involving foreign-flagged vessels; (2) the application of technological and engineering-based approaches for oil spill monitoring and control; (3) preventive measures related to technical failures, human error, and intentional violations; (4) regulatory performance in prevention, emergency response, investigation, and prosecution; and (5) the consistency of Thailand's monitoring systems and legal framework with international marine environmental law principles.

In Phase 2, following the qualitative interviews, each informant was asked to provide quantitative assessments of the perceived effectiveness of government monitoring and supervision across key operational stages, including prevention, emergency response, and legal action. These assessments were rated on a five-point Likert scale to enable comparative evaluation across different operational scenarios.

This approach was adopted to ensure that the quantitative results (mean and SD) reflected the consensus of high-level practitioners. In this context, oil spill monitoring and enforcement involve technically complex systems and require coordination. Accordingly, expert elicitation provides a more suitable analytical approach by capturing specialized expertise and strategic insights from senior practitioners and policymakers, rather than statistical generalization to a broader population. The structured questionnaire was developed based on insights from the qualitative phase, ensuring conceptual alignment between the two phases of the study.

The data collection instrument was designed to support a systematic assessment of the governance framework for ship-source oil spill management and to enable a gap analysis between international legal requirements and their practical implementation within the Thai context. Subject-matter experts reviewed the semi-structured interview questions and the five-point Likert scale to ensure content validity, including assessment using the IOC index to refine the clarity, relevance, and reliability of the research tools, as approved by the IRB of Ramkhamhaeng University.

2.2 Data Analysis and Integration of Findings

Qualitative and quantitative data were analyzed in parallel in accordance with the mixed-methods research design. Qualitative data obtained from the semi-structured interviews were subjected to thematic analysis. Interview transcripts and detailed field notes were systematically reviewed, coded, and organized to identify recurring patterns and key themes related to law enforcement, technological capacity, institutional coordination, and preventive measures in ship-source oil spill management. This analysis aimed to identify structural, legal, and operational constraints affecting the effectiveness of monitoring and enforcement within Thailand's port governance framework.

Quantitative data derived from the five-point Likert scale assessments were analyzed using descriptive statistical methods. Mean values and standard deviations were calculated to evaluate stakeholders' perceptions of government performance across three core operational stages: prevention, emergency response, and investigation and prosecution. These measures were used to compare perceived performance levels across different operational scenarios and causes of oil spill incidents, as well as to assess the consistency of regulatory implementation.

The integration of qualitative and quantitative findings was conducted through comparative and interpretive analysis. Qualitative insights were used to explain and contextualize patterns observed in the quantitative results, thereby supporting a systematic gap analysis between international marine environmental law standards and their practical implementation in Thailand. This integrated analysis provided a robust empirical basis for identifying governance weaknesses and formulating evidence-based recommendations to strengthen ship-source oil spill monitoring and legal enforcement in Thailand's major ports.

3. Results

This section presents the study findings from both qualitative and quantitative analyses. The qualitative results highlight key themes derived from stakeholder perspectives on ship-source oil spill

management, followed by quantitative findings on perceived government effectiveness in monitoring, response, and enforcement.

3.1 Qualitative findings: key challenges in ship-source oil spill management

The analysis identified five major themes reflecting underlying governance challenges in ship-source oil spill management. These themes are summarized in Table 1.

Table 1 summarizes the five major themes derived from the thematic analysis, together with their core analytical focus and key issues identified by stakeholders. The following subsections elaborate on each theme and provide a detailed qualitative account of the institutional, technological, and operational challenges shaping ship-source oil spill governance in Thailand.

Table 1. Summary of qualitative themes on ship-source oil spill management

Theme	Core Focus	Key Issues Identified
Theme 1: Limitations in Legal Enforcement and Regulatory Structure	Institutional and legal governance	Fragmented mandates; overlapping agency responsibilities; jurisdictional ambiguity; enforcement challenges involving foreign-flagged vessels
Theme 2: Insufficient Application of Monitoring and Surveillance Technologies	Technological capacity for enforcement	Limited real-time monitoring coverage; insufficient reliability of monitoring data for legal evidence; underutilization of technology in investigation and prosecution
Theme 3: Systematic Approaches to Oil Spill Prevention	Preventive governance mechanisms	Reactive management orientation; weaknesses in inspection regimes; inconsistent maintenance and preventive controls
Theme 4: Human Factors and Operational Risks	Operational and behavioral dimensions	Human error during oil transfer operations; inconsistent training and supervision; variability in operational standards
Theme 5: Interagency Integration and International Cooperation	Coordination and transboundary governance	Limited inter-agency information sharing; lack of integrated monitoring systems; need for international cooperation in cross-jurisdictional cases

Theme 1: Limitations in legal enforcement and regulatory structure

The interview findings indicate that, although Thailand has adopted relevant international maritime environmental conventions and enacted domestic legislation on oil pollution prevention, the effectiveness of enforcement remains limited in practice. Most respondents identified the regulatory framework as structurally fragmented, characterized by the involvement of multiple agencies with overlapping responsibilities. This fragmentation was consistently highlighted as a major barrier to effective enforcement, as it often leads to unclear institutional authority and delays in enforcement actions.

Furthermore, interviewees emphasized the particular challenges associated with enforcing environmental laws against foreign-flagged vessels. These challenges include ambiguities in jurisdiction, procedural delays, and difficulties in coordinating legal processes across responsible agencies. Such

constraints were perceived to significantly undermine the operational capacity to investigate and prosecute oil pollution cases, especially within large port areas. Overall, the interview data suggest that improving enforcement effectiveness requires clearer institutional coordination and more integrated implementation of existing regulatory frameworks, rather than the introduction of additional legal instruments alone.

Theme 2: Insufficient application of monitoring and surveillance technologies

A second major theme concerns the limited application of modern monitoring and surveillance technologies in oil spill detection and enforcement. Respondents consistently noted that existing technological systems are insufficient for continuous, real-time monitoring of oil discharges and spill movements, particularly during nighttime operations and across extensive maritime areas surrounding major ports.

In addition to these operational limitations, interviewees expressed concern regarding the legal utility of current monitoring data. Monitoring outputs were often perceived as lacking the technical reliability and evidentiary credibility required for use in judicial proceedings, thereby constraining their effectiveness in supporting investigation and prosecution. As a result, the potential of technology to function as an enforcement enabler remains underutilized.

From the stakeholders' perspective, enhanced and integrated monitoring systems capable of generating verifiable and legally defensible data were viewed as essential for strengthening enforcement capacity. Such systems were expected to improve situational awareness, facilitate inter-agency coordination, and enable more effective detection of covert illegal oil discharges.

Theme 3: Systematic approaches to oil spill prevention

The interviews reveal a shared view that oil spill management in Thailand remains predominantly reactive, with greater emphasis placed on emergency response than on preventive control. Respondents emphasized that effective prevention requires a systematic governance approach encompassing regular vessel and port inspections, strict enforcement of maintenance standards, and oversight of repair and modification procedures.

Stakeholders indicated that weaknesses in inspection regimes and preventive maintenance increase the likelihood of technical failures and operational accidents that may lead to oil spill incidents. Preventive governance was therefore viewed as a critical component of effective marine environmental protection, particularly in high-risk port environments. Interviewees suggested that strengthening preventive mechanisms through more consistent inspection practices and risk-based monitoring would reduce spill risks and enhance overall management outcomes.

Theme 4: Human factors and operational risks

Human error emerged as a significant contributor to oil spill incidents, particularly during oil transfer and handling operations. Interviewees noted that, despite the presence of technical systems and regulatory controls, operational mistakes by ship crews and port personnel remain a persistent risk.

Contributing factors identified by respondents included inconsistent training standards, limited supervision, and variations in operational procedures among vessels and operators. These findings suggest that technological and regulatory measures alone are insufficient to address operational risks without parallel efforts to strengthen human capacity. Improved training, competency development, and operational discipline were therefore identified as essential complements to technical and legal controls in reducing spill incidents and supporting effective enforcement in practice.

Theme 5: Interagency integration and international cooperation

The final theme highlights the importance of integrated interagency collaboration and international cooperation in managing ship-source oil pollution. Respondents widely agreed that oil

pollution from ships is a transboundary issue that cannot be effectively addressed by a single agency or within national jurisdiction alone.

Interviewees emphasized the need for enhanced information sharing, coordinated monitoring systems, and joint investigations among domestic agencies. In addition, cooperation with international organizations and neighboring states was viewed as essential, particularly in cases involving high-risk or foreign-flagged vessels operating across multiple jurisdictions. From the stakeholders' perspective, stronger interagency and international integration was regarded as a key factor in improving enforcement efficiency and addressing complex oil pollution incidents in major port areas.

3.2 Quantitative findings: perceived effectiveness of government oversight in ship-source oil spill management

Following the qualitative interviews, informants provided quantitative assessments of the perceived effectiveness of government monitoring and supervision across key stages of ship-source oil spill management: prevention, emergency response, and legal action. The quantitative results are presented below according to these operational stages.

3.2.1 Perceived effectiveness of government oversight in oil spill prevention

Stakeholders' assessments of the effectiveness of government oversight in preventing oil spill incidents arising from different causes are presented in Table 2. Overall, preventive monitoring related to navigational accidents received the highest effectiveness score among all categories, suggesting strong confidence in existing preventive measures for overt maritime operational risks.

In contrast, the preventive effectiveness of government oversight was rated at a moderate level for oil spill incidents caused by technical failures of vessels or equipment and human error during oil transfer operations. These comparatively lower ratings indicate that preventive monitoring and oversight mechanisms are perceived to be less effective in addressing risks associated with complex technical systems and operational practices. Variability in stakeholder responses, particularly with respect to technical failures, suggests differences in professional perspectives and institutional roles among the respondents.

Similarly, although the prevention of illegal oil discharges received slightly higher ratings than those related to technical failures and human error, the results indicate only a moderate level of perceived deterrence effectiveness. When considered in conjunction with the qualitative findings, this pattern points to potential limitations in existing preventive measures, particularly in their capacity to deter intentional violations under conditions of enforcement complexity, including cases involving foreign-flagged vessels.

Table 2. Effectiveness of government oversight in preventing major causes of oil spills

Cause of Oil Spill	Mean	Standard Deviation	Level of Efficiency
Accidents from Navigation	4.27	0.45	High
Technical failures of vessels or equipment	3.09	0.67	Moderate
Human error during oil transfer operations	3.09	0.51	Moderate
Illegal discharge of oil	3.45	0.50	Moderate

Note: The level of efficiency is interpreted based on the mean score as follows: 1.00–1.80 = Very Low; 1.81–2.60 = Low; 2.61–3.40 = Moderate; 3.41–4.20 = High; and 4.21–5.00 = Very High. This interpretation applies to Tables 2–5.

3.2.2 Perceived Effectiveness of Government Oversight in Emergency Response and Control

Stakeholders' perceptions of the effectiveness of government oversight in controlling and responding to oil spill incidents are presented in Table 3. Across incident categories, emergency response capacity received relatively high effectiveness ratings for incidents associated with navigational accidents and illegal oil discharges. However, effectiveness ratings remained at a moderate level for incidents caused by technical failures and human error. This pattern mirrors the prevention-stage findings and indicates that response effectiveness varies depending on the underlying cause of the incident. The persistence of moderate ratings for technical and human-related incidents reinforces qualitative insights regarding operational complexity and uneven enforcement capacity.

Taken together, these findings suggest that while emergency response mechanisms are generally effective, their performance is less consistent in scenarios involving less visible or more operationally complex causes of oil spills.

Table 3. Effectiveness of government oversight in emergency response and control

Cause of Oil Spill	Mean	Standard Deviation	Level of Efficiency
1. Accidents from Navigation	4.18	0.39	High
2. Technical failures of vessels or equipment	3.27	0.75	Moderate
3. Human error during oil transfer operations	3.36	0.48	Moderate
4. Illegal discharge of oil	3.73	0.45	High

3.2.3 Perceived Effectiveness of Government Oversight in Investigation and Prosecution

Table 4 shows stakeholders' assessments of government effectiveness in the post-incident phases of investigation and legal proceedings. The data indicate notable variation in perceived enforcement effectiveness across different types of oil spill incidents.

Investigation and prosecution associated with navigational accidents were rated as relatively effective, consistent with the clearer attribution of causation and responsibility in such cases. By comparison, effectiveness ratings declined to a moderate level for incidents involving technical failures and human error, indicating greater difficulty in establishing liability.

Most critically, the investigation and prosecution of illegal oil discharges received the lowest ratings among the incident categories and were rated as low. The consistency of responses indicates a shared stakeholder perception of limited enforcement effectiveness in this area. These results are consistent with qualitative evidence pointing to constraints related to detection capability, evidentiary adequacy, jurisdictional complexity, and the enforcement of regulations against foreign-flagged vessels.

Table 4. Perceived effectiveness of government oversight in investigating and prosecuting major causes of oil spills

Cause of Oil Spill	Mean	Standard Deviation	Level of Efficiency
Accidents from Navigation	4.00	0.60	High
Technical failures of vessels or equipment	3.18	0.39	Moderate
Human error during oil transfer operations	3.00	0.60	Moderate
Illegal discharge of oil	2.73	0.45	Low

3.2.4 Perceived Impact of Monitoring Systems on the Effectiveness of Oil Spill Management Processes

Stakeholders assessed the perceived impact of monitoring systems on the effectiveness of key stages in oil spill management, as summarized in Table 5. The results indicate that monitoring systems were perceived to have a high level of impact on the effectiveness of oil spill management across all stages. Among the assessed stages, emergency response management received the highest perceived impact rating, followed by incident prevention, investigation and legal action, pollution management planning, and environmental restoration, respectively.

Although the perceived impact of monitoring systems on pollution management planning and environmental restoration remained within the high category, these stages received comparatively lower ratings than other management stages. This pattern indicates that the role of monitoring systems is more clearly recognized in stages that rely on real-time information and operational decision-making, such as emergency response and incident prevention, whereas their perceived impact is less pronounced in longer-term or post-incident management processes, including planning and environmental restoration.

The results show that monitoring systems are perceived as highly effective, particularly in cases involving visible oil spills that can be directly detected and controlled. However, monitoring is less effective in detecting non-visible violations, such as illegal discharges at night or equipment-related failures. These limitations are more pronounced for foreign-flagged vessels due to constraints in data access, limited inspection time, and protections under international law.

Table 5. Perceived impact of monitoring systems on oil spill management processes

Process in Oil Spill Management	Mean	Standard Deviation	Level
Pollution Management Planning	4.00	0.60	High
Incident Prevention	4.27	0.45	High
Emergency Response Management	4.45	0.50	High
Investigation and Legal Action	4.18	0.39	High
Environmental Restoration	3.91	0.51	High

4. Discussion

This section integrates and interprets findings from both qualitative and quantitative data to develop a comprehensive understanding of the challenges and opportunities in strengthening Thailand's regulatory framework for ship-source marine oil pollution control. Evidence from both sets of data reveals that the current system is strong in dealing with visible spill incidents, while exhibiting significant weaknesses in proactive prevention and legal enforcement against covert and difficult-to-detect violations. These findings underscore an urgent need for strategic investment and structural reform (UNEP, 2019).

A key finding is the pronounced disparity in the perceived effectiveness of government oversight across different dimensions of ship-source oil spill management. While stakeholders generally regarded surveillance and response capacities for clearly observable incidents, such as navigation-related accidents, as highly effective, perceived effectiveness declined markedly when addressing less visible causes, including technical failures and human error. Most concerning is the finding that effectiveness was rated as low for the investigation and prosecution of illegal oil discharges. This pattern suggests that the existing system is predominantly reactive rather than preventive in nature: it is well equipped to manage overt crises, yet

struggles to deter, detect, and prosecute clandestine activities or incidents where the pollution source cannot be readily identified. Such incidents may nonetheless account for a substantial proportion of oil pollution entering the marine environment (De Kerf et al., 2024).

This enforcement gap related to covert violations directly aligns with the qualitative findings from stakeholder interviews, which emphasized the need for substantial upgrades in surveillance technology. Calls for integrated, advanced monitoring systems capable of high-precision, continuous operation under all weather conditions and during nighttime directly address the weaknesses identified in the quantitative data. Such systems are critical for shifting the governance approach from reactive to proactive, enabling the detection of illegal discharges that routine patrol-based and labor-intensive monitoring cannot adequately capture. Moreover, these technologies play a crucial role in generating legally defensible evidence to support investigation and prosecution. The convergence of views across all interviewed agencies indicates that technology is not merely an auxiliary improvement, but rather a central enabling factor linking regulatory intent to effective enforcement outcomes (Hadavand et al., 2022).

The analysis highlights challenges associated with enforcing Thai environmental regulations on vessels, particularly foreign-flagged vessels, which constitute a significant jurisdictional and structural constraint. In cases involving technical failures of vessels or equipment, as well as human error during oil transfer operations, enforcement is limited by restricted access to inspection data from the country of origin, including records on equipment standards and crew operational control. These limitations have contributed to repeated oil leakage incidents during transfer operations, particularly due to defective pipelines or valves. Thailand's legal framework may need amendments to strengthen inspection authority across different types of vessels and to recognize digital monitoring data, such as satellite, AIS records, and sensor-based evidence, as admissible evidence in law enforcement processes. Such legal recognition would strengthen evidentiary standards, improve the reliability of inspections, and potentially enhance prosecution outcomes, particularly in complex cases. The effectiveness of prevention and response to incidents resulting from technical failures and human error was assessed at a moderate level. Such incidents are often closely tied to equipment standards and crew operational procedures governed by international conventions, which present limitations for inspection and enforcement when applied to vessels under foreign jurisdiction. These jurisdictional and diplomatic challenges cannot be resolved through technological solutions alone but require stronger international cooperation (Govindarajan et al., 2021).

Furthermore, human error was found to be a contributing factor, underscoring the importance of strengthening the human–technology nexus in enforcement. Integrating automated monitoring systems, real-time sensors, and remote surveillance technologies can reduce reliance on manual operations and improve early anomaly detection.

Overall, the findings indicate that the effectiveness of surveillance and control measures for ship-source oil pollution in major Thai ports depends on multiple interrelated factors. These include the robustness of legal enforcement mechanisms, the adoption of advanced technologies, systematic preventive management, human resource development, and the strength of both inter-agency coordination and international collaboration.

Policy Recommendations, based on the synthesis of quantitative findings and expert stakeholder perspectives, the study finds that while response frameworks for large-scale and highly visible incidents are perceived as robust, the system's capacity for proactive prevention and prosecution of illegal activities remains a critical weakness. Addressing these gaps requires an integrated, multidimensional approach encompassing technological investment, legal reform, and institutional cooperation. The following policy recommendations are proposed.

First, priority should be given to the development and deployment of modern surveillance technologies. Investment is needed in advanced, integrated monitoring systems capable of comprehensive and continuous observation, enabling accurate real-time detection and tracking of pollution sources. Particular emphasis should be placed on technologies that function effectively during nighttime and under adverse weather conditions.

Second, the legal and enforcement framework should be strengthened through more rigorous implementation of existing laws and regulations, particularly those targeting illegal oil discharges. This should be accompanied by a clearer delineation of roles and responsibilities among relevant government agencies to enhance operational integration, reduce institutional overlap, and improve enforcement efficiency.

Third, international cooperation should be enhanced through strengthened coordination, data sharing, and collaborative mechanisms with international organizations and neighboring countries. Such cooperation is essential for the surveillance and regulation of high-risk vessels, as well as for addressing jurisdictional challenges associated with enforcement against foreign-flagged ships operating in Thai waters.

Finally, integrated response and investigation processes should be developed through the establishment of standardized operational guidelines that fully leverage modern technologies across all stages of oil spill management. These stages include proactive prevention, rapid emergency response, and systematic evidence collection capable of supporting effective investigation and legal prosecution.

Future research may explore the possibility of applying this framework to ASEAN member countries facing similar jurisdictional and operational challenges, thereby enhancing its regional significance.

5. Conclusions and recommendations

This study examined the effectiveness of ship-source oil spill monitoring and law enforcement in Thailand's major ports using a mixed-methods approach that integrated stakeholder interviews with quantitative assessments of perceived government performance. The findings demonstrate that the effectiveness of oil spill governance varies significantly across incident types and enforcement stages, reflecting limitations in practical implementation rather than deficiencies in formal legal frameworks.

Quantitative results indicate that government oversight is perceived as highly effective in managing navigation-related oil spill incidents, particularly in emergency response and visible accident management, where institutional responsibilities, operational procedures, and evidentiary conditions are relatively clear. However, perceived effectiveness declines to moderate levels for incidents involving technical failures and human error, and to low levels for the investigation and prosecution of illegal oil discharges. These patterns suggest that current governance mechanisms are more effective in responding to overt and observable incidents than in addressing covert, operationally complex, or intentional violations.

Qualitative findings provide further insight into these disparities. Stakeholders identified the limited deployment of advanced monitoring technologies, fragmented inter-agency coordination, and constraints in evidentiary capacity as critical barriers to effective enforcement, particularly for foreign-flagged vessels and deliberate illegal discharges. Although Thailand has adopted relevant international conventions and domestic legislation, enforcement remains constrained by jurisdictional complexities, uneven access to operational data, and insufficient technological integration among responsible agencies.

A key contribution of this study is the empirical demonstration that monitoring technology plays a mediating role between regulatory intent and enforcement outcomes. Without reliable, continuous, and legally defensible monitoring data, enforcement mechanisms lack the operational foundation necessary to

support investigation, prosecution, and deterrence. Advanced surveillance and detection technologies are therefore not merely supplementary tools but essential enablers of effective maritime environmental governance, particularly for proactive prevention and accountability.

Overall, the findings indicate that strengthening ship-source oil spill governance in Thailand requires a shift from a predominantly reactive enforcement model toward a more integrated, technology-enabled, and preventive governance approach.

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