MARINE SPILL DETECTION AND ANALYTICS SYSTEM

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Abstract - The Marine Spill Detection And Analytics System is a web-based tool designed to assess and visualize the environmental effects of oil spills in marine ecosystems. It includes an interactive calculator that estimates the spread of a spill using advection-diffusion principles, predicts how the oil concentration decreases over five days with first-order decay modeling, and calculates the likely impact on marine organisms based on exposure and mortality rates. Users can enter the type and amount of oil spilled, and the system provides instant results on spill range, recovery concentration, and estimated marine life deaths. The platform offers a simple and intuitive interface, helping users such as environmental officers, disaster responders, and coastal communities make faster, more informed decisions. The project demonstrates how real-time spill modeling can support early intervention and raise awareness of ecological risks associated with oil pollution.

Keywords: oil spill, marine pollution, ecological modeling, impact calculator, environmental monitoring, web-based tool.

1. INTRODUCTION

Oil spills are among the most catastrophic environmental disasters affecting marine ecosystems, often resulting in long-term ecological damage and severe socio-economic consequences. The increasing frequency of offshore drilling operations, oil transportation through sea routes, and industrial activities near coastlines have heightened the risk of unintentional oil discharge. Such events not only disrupt aquatic biodiversity but also contaminate drinking water, degrade fishing industries, and threaten public health across coastal regions. As these consequences intensify, the need for real-time spill detection and comprehensive analytics becomes critically important.

Conventional spill response mechanisms are often delayed, reactive, and fragmented, relying heavily on manual reports or satellite data that may not be processed in real time. This lag limits the efficiency of containment and restoration efforts. Furthermore, a lack of predictive modelling restricts authorities and researchers from assessing potential outcomes and planning appropriate responses in advance. It is within this context that the *Marine Spill Detection and Analytics System* has been developed to bridge the gap between oil spill detection and actionable insights.

This system offers an integrated digital platform combining real-time monitoring, historical spill visualization, and scientific modelling tools in a user-friendly interface. It enables users to view live data from spill events across the globe, search incidents by region, and explore spill characteristics through an interactive map. Central to the system is a spill calculator that estimates three key outcomes: the projected spread of the oil spill, the remaining oil concentration over time using first-order decay kinetics, and the estimated marine organism mortality based on exposure levels and oil type. By simplifying access to complex environmental data and providing scientifically grounded estimates, the system empowers environmental agencies, researchers, policymakers, and coastal communities to respond more effectively.

The *Marine Spill Detection and Analytics System* not only facilitates rapid decision-making but also supports long-term environmental monitoring and public awareness. Through its modular structure and web-based deployment, it serves as a scalable and educational tool aimed at strengthening marine environmental protection efforts worldwide

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2. Body of Paper

2.1 Spill Monitoring and Visualization

The *Marine Spill Detection and Analytics System* offers an intuitive and dynamic interface for tracking marine oil spills globally. The interactive map component visualizes spill locations using custom markers that display key attributes such as region, volume, spill type, date, and time. These details are extracted from simulated satellite data and organized for accessibility. Section 1 introduced the motivation for real-time monitoring, and here we expand on its execution. The visualization allows environmental analysts, researchers, and decision-makers to observe spill clusters, assess geographic risk, and prioritize regions for restoration. Users can also filter spills by region (e.g., Bay of Bengal, Arabian Sea) or perform keyword searches using the built-in search bar, as detailed in Sec. 2.4. This tool makes complex geospatial data easily interpretable through clean and modern user interface design.

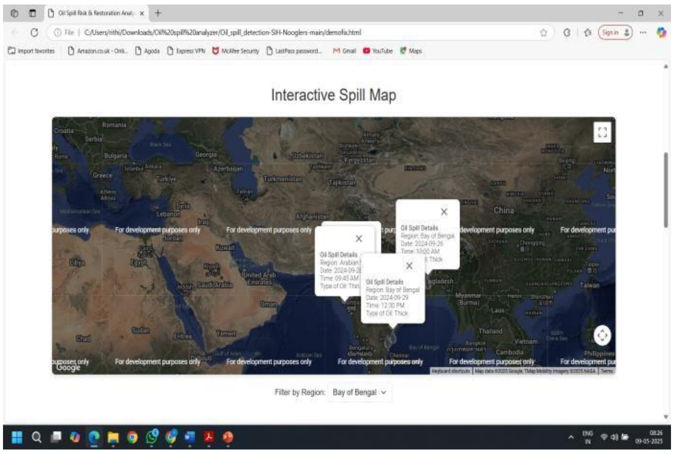

Fig-1: Interactive Spill Map

2.2 Impact Estimation Calculator

One of the system's core components is the spill impact calculator, which estimates the physical and ecological impact of a spill based on user inputs. The calculator uses validated scientific models to simulate real-world outcomes. The first model, advection-diffusion, estimates the distance the oil spreads in water. This takes into account water current velocity and molecular diffusion over a time constant. The second model is based on first-order decay kinetics, which calculates how much of the oil concentration remains after a fixed period (five days) assuming natural degradation processes. Finally, an ecological mortality model estimates the number of marine organisms likely to be affected. This is based on organism density, exposed area, oil toxicity, and mortality rate. As described in Sec. 2.3, these outputs are presented to the user instantly upon data submission. This approach empowers quick evaluation of emergency response requirements.

2.3 Data Inputs and Output Metrics

The calculator accepts two primary inputs: volume of oil spilled (in liters) and the oil type (light, medium, or heavy). At the first manifestation of each type, the system assigns parameters including water current speed, diffusion coefficient, decay rate, and mortality factor. For example, light oil has a faster spread but degrades quicker, while heavy oil spreads slower and persists longer in the marine environment. These input variables feed into three equations that output the spill range (in meters), recovery concentration (in liters remaining after 5 days), and estimated marine organism deaths. These metrics help responders gauge the environmental severity of each incident. As illustrated in Fig. 2, each output is clearly displayed in a dedicated results section for ease of analysis. By adjusting the oil type or quantity, users can simulate various spill scenarios and compare outcomes.

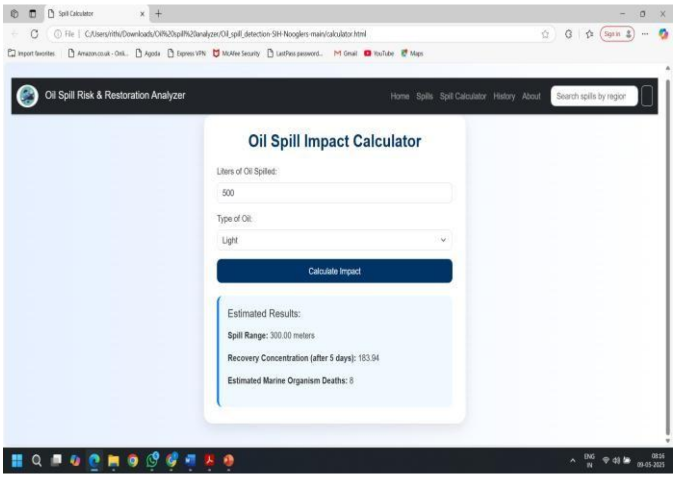

Fig -2: Oil spill impact calculator

2.4 Historical Data, Search, and Filtering

The platform includes a dedicated section to review past oil spills, offering tabulated data such as region, date, time, satellite source, and spill area. This supports historical analysis and helps identify recurring risk zones. The search functionality allows users to locate incidents based on geographic keywords. Region filtering also improves usability by enabling users to narrow down specific data points. The design ensures that large-scale data can be effectively navigated even by non-technical users. Section 2.1 showed how this map-based interactivity supports transparency and real-time awareness, while this section emphasizes long-term pattern recognition. These supporting features make the system valuable not just for real-time tracking, but also for archival analysis and environmental reporting.

2.5 Formulas:

i) Estimating range of oil spill:

$$\frac{\partial C}{\partial t} + \mathbf{u} \cdot \nabla C = D \nabla^2 C$$

- u is the velocity field of currents and wind.
- D is the diffusion coefficient.
- C is the oil concentration.

ii) Estimating recovery time of oil spill:

$$C(t) = C_0 e^{-kt}$$

- C0 is the initial concentration.
- k is the decay constant, specific to each process.
- C(t) is the concentration at time t.

iii) Find how many linving organism dead in the oil spill:

Mortality Estimate = Population Density × Oil Exposure Probability × Mortality Rate

- Population Density is the number of organisms per unit area.
- Oil Exposure Probability is the likelihood that an organism encounters oil.
- Mortality Rate is the probability that an exposed organism dies due to oiling.

3. CONCLUSIONS

The *Marine Spill Detection and Analytics System* serves as an effective digital solution for real-time oil spill monitoring, impact estimation, and data-driven environmental response. By integrating interactive mapping, historical spill data visualization, and a scientifically grounded calculator, the system addresses critical gaps in marine pollution assessment. Its ability to project spill spread, predict recovery concentrations, and estimate ecological damage makes it a practical tool for researchers, emergency responders, and policy authorities. This project demonstrates that a web-based system, equipped with simplified user input and dynamic output metrics, can significantly enhance environmental situational awareness and decision-making. It bridges the gap between raw data and actionable insights, ensuring that marine environmental risks are managed proactively rather than reactively. The online version of this platform offers public accessibility and educational value. Like the LNCS Online model, institutions and stakeholders can access the system's visual features and summaries, while more technical details and advanced functionalities may be extended through secured access or data partnerships. The project also sets a foundation for future enhancements, including integration with live satellite feeds, predictive analytics, and automated reporting modules for environmental agencies.

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