18th International Conference on Environmental Science and Technology

Athens, Greece, 30 August to 2 September 2023

Development of Scenario-based Decision-Making Framework for Marine Oil Spill Waste Management

HOSSEINIPOOYA SEYED ASHKAN[1], LI JIANBING[1*]

[1]Environmental Engineering Program, School of Engineering, University of Northern British Columbia, 3333 University Way, Prince George, British Columbia, Canada V2N 4Z9

*corresponding author:
e-mail: Jianbing.Li@unbc.ca

Abstract This study developed a scenario-based decision-making framework to help select the appropriate strategy to deal with marine oil spill response waste by considering different impact factors, including the type of spilled oil, the quantity and quality of waste, the capacity of transportation, the capacity and location of treatment and disposal facilities, and the feasibility of strategies. Based on the combination of impact factor conditions, 1600 and 4608 input scenarios were generated for liquid and solid oily waste, respectively. An optimization model with an objective of minimizing costs was developed and programmed in RStudio to evaluate each input scenario. The real-world data was collected for the optimization modeling parameters. The results indicated that the best strategy for managing liquid oily waste from spilled refined oil (e.g., diesel and bunker) should be the sending of waste to a processing facility for physical and chemical separation. For solid oily waste, pyrolysis is the best option if available followed by incineration.

Keywords: decision making, marine oil spill response, optimization, scenario, waste management

1. Introduction

Environmental disasters caused by marine oil spills can negatively impact the environment, public health, and local economy (Li et al., 2016). Offshore oil spills continuously happen worldwide despite significant progress in prevention measures (Hu et al., 2020; Hosseinipooya et al., 2022). For example, more than 140 large oil spills occurred between 1907 and 2014 that released over 7 million tons of oil into the environment (Li et al., 2016). The largest oil spill in history is the Deepwater Horizon oil spill, where nearly 4 million barrels of oil were released into the Gulf of Mexico, resulting in enormous economic and environmental damages (EPA, 2022).

After an oil spill, responders apply various methods, including mechanical containment and recovery, use of chemical dispersants, bioremediation, and in-situ burning to rapidly clean up the spilled oil and reduce the environmental impacts (Hu et al., 2020; Mohammadiun et al., 2021). However, some response actions usually result in the generation of a considerable amount of oily liquid and solid wastes (e.g., oil-contaminated seawater; oily PPE, sorbents, and debris) (Saleem et al., 2022; Hosseinipooya et al., 2022). Many factors, such as the type of spilled oil, weather conditions, response equipment efficiency, and the response arrival time, affect the quantity of generated oil spill response waste (OSRW) (Hosseinipooya et al., 2022). Studies have shown that the quantity of OSRW might be ten times more than the volume of the original spilled oil (IPIECA-IOGP, 2016; POSOW, 2016).

This study aims to develop a scenario-based decision-making framework to help identify the most appropriate OSRW management strategies under different conditions (e.g., waste quantity, waste quality, and location and capacity of facilities). The framework was developed using the analysis of results from the evaluation of input scenarios generated based on the combination of impact factors in OSRW management. An optimization model was developed for each waste type to find the optimum solution for each possible scenario. The optimization model is to minimize the total net costs. The development of such a framework is of high importance to reduce waste management costs and increase the chance of making revenue out of collected oily waste by taking the most suitable strategy under different conditions.

2. Methodology

Figure 1. presents an overview of the methodology of this study. In this study, each impact factor in OSRW management consists of some levels resulting in hypothetical data generation for each type of waste. Based on the combination of hypothetical data of all OSRW management impact factors, 1600 input scenarios for liquid waste and 4608 input scenarios for solid oily waste were generated. An optimization model was applied for each type of waste to minimize the net costs to give optimum decision variables (i.e., selected strategy and assigned waste quantity to each strategy) for each input scenario. In addition to hypothetical data, data collection was needed for some fixed modeling parameters to run the optimization model for each input scenario. R studio (version 1.3.1093) was used to run the model and integrate input scenarios and the optimization model for each type of waste. R studio could report and store a results table in less than a few seconds, including all optimum decisions and the objective value for all input scenarios for each type of oily waste. Results from evaluating all input scenarios

were then summarized into similar categories in terms of their effect on the selection of optimum strategies for each type of waste. For example, if the most appropriate strategy for a number of strategies was the same, those scenarios were categorized into a group. Based on the summary of results, some “If-Then” rules were generated to develop a scenario-based decision-making framework for OSRW management strategies. The decision-making framework provides the most monetary beneficial strategies to deal with each OSRW under different scenarios (conditions).

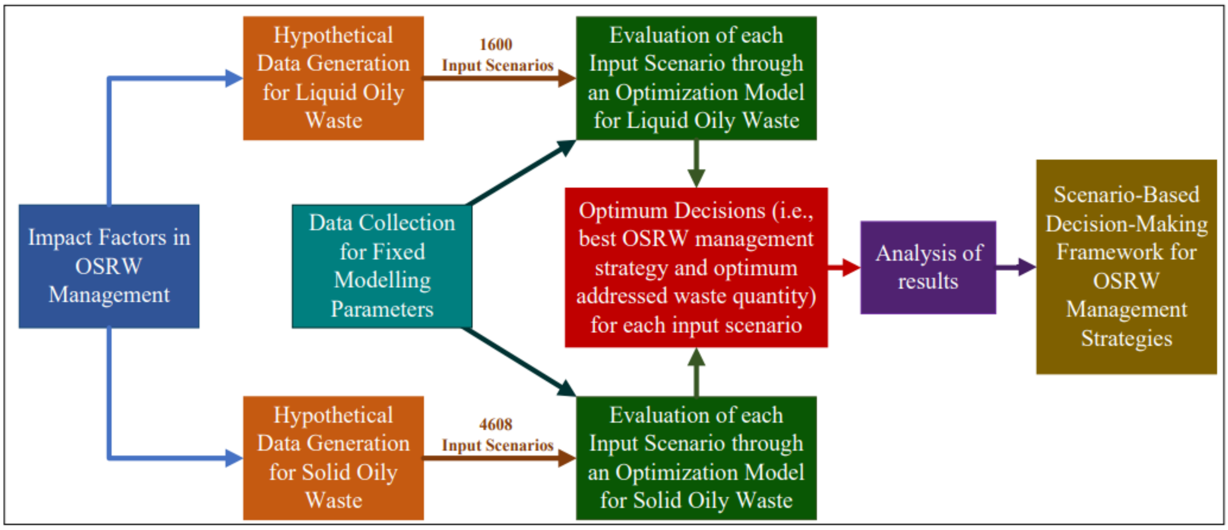

Figure 1. Overview of the methodology framework

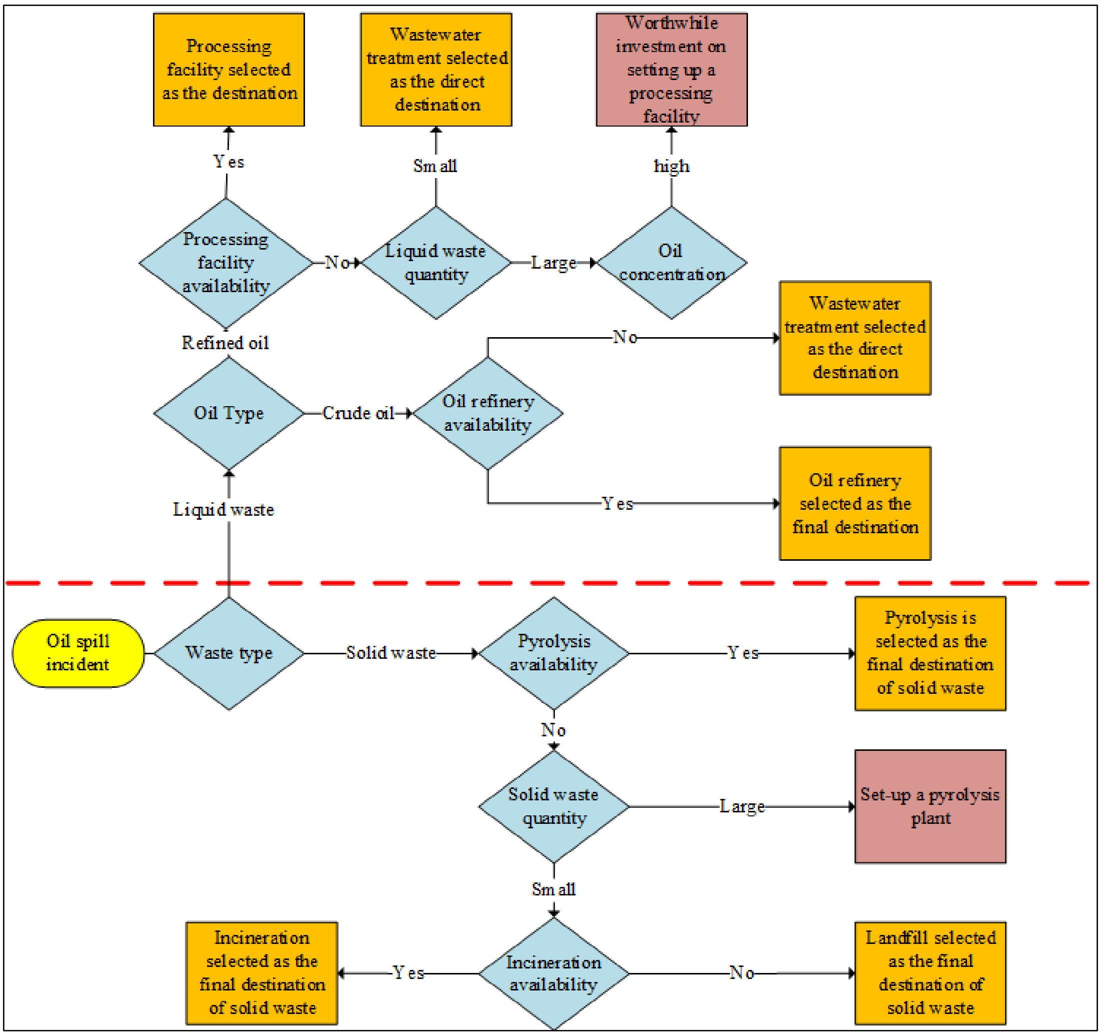

Figure 2. Scenario-based decision-making framework for oil spill waste management

3. Results

Figure 2. shows the scenario-based decision-making framework developed for oil spill waste management. The figure presents the most financially beneficial decision to deal with each type of collected oily waste under different conditions. The results demonstrated that the strategy to manage each type of waste under different scenarios might vary. As presented in Figure 2., the best financial decision to deal with liquid oily waste from spilled refined oil is to send the oily waste to a processing facility as much as the capacity allows. If the processing facility is unavailable, the optimum decision depends on the quantity of liquid oily waste and its oil content. To manage liquid oily waste, if the type of spilled oil is crude oil and the oil refinery is available, the suitable strategy can be to send liquid oily waste to wastewater treatment or an oil refinery, depending on the waste quality. For solid oily waste, pyrolysis is the best option if available; incineration is the second most financially beneficial destination for solid waste management. Moreover, the results demonstrated the importance of establishing the processing facility for liquid and the pyrolysis plant for solid oily waste management.

4. Conclusion

This study developed a scenario-based decision-making framework to provide decision-makers with the most financially beneficial strategies to deal with each type of oily waste under different conditions of impact factors, including the type of spilled oil, waste quantity, waste quality, and capacity of treatment and disposal facilities. The evaluation of several input scenarios generated from the combination of hypothetical levels of all addressed impact factors was analyzed to develop the framework. The results illustrated that a different waste quantity or quality might significantly change the optimum destination of oily waste. The study provided an effective tool for oil spill response organizations or waste management companies to optimize their decision-making in managing liquid and solid oily waste generated after oil spills.

References

Hosseinipooya, S. A., Hu, G., Lee, K., Li, J., Ng, K. T. W., & Vu, H. L. (2022), A system dynamics modeling approach for estimation of oily waste generation from marine oil spill response: A case study of an oil spill in Central Coast of British Columbia. *Frontiers in Environmental Science*, **801**.

Hu, G., Mohammadiun, S., Gharahbagh, A. A., Li, J., Hewage, K., & Sadiq, R. (2020), Selection of oil spill response method in Arctic offshore waters: A fuzzy decision tree based framework. *Marine Pollution Bulletin*, **161**, 111705.

International Petroleum Industry Environmental Conservation Association, & International Association of Oil and Gas Producers. (2016), Oil spill waste minimization and management guideline. Retrieved from *https://www.ipieca.org/resources/good-practice/oil-spill-waste-minimization-and-management/*, accessed on July 29, 2021.

Li, P., Cai, Q., Lin, W., Chen, B., & Zhang, B. (2016), Offshore oil spill response practices and emerging challenges. *Marine Pollution Bulletin*, **110(1)**, 6-27.

Mohammadiun, S., Hu, G., Gharahbagh, A. A., Mirshahi, R., Li, J., Hewage, K., & Sadiq, R. (2021), Optimization of integrated fuzzy decision tree and regression models for selection of oil spill response method in the Arctic. *Knowledge-Based Systems*, **213**, 106676.

Preparedness for Oil-polluted Shoreline cleanup and Oiled Wildlife interventions (POSOW). (2016), Oil Spill Waste Management Manual. Retrieved from *https://www.posow.org/documentation/wasteweb.pdf*, accessed on May 2, 2022.

Saleem, S., Hu, G., Li, J., Hewage, K., & Sadiq, R. (2022), Evaluation of offshore oil spill response waste management strategies: A lifecycle assessment-based framework. *Journal of Hazardous Materials*, **432**, 128659.

Uniated States Environmental Protection Agency (EPA). (2022), Deepwater Horizon – BP Gulf of Mexico Oil Spill. Retrieved from *https://www.epa.gov/enforcement/deepwater-horizon-bp-gulf-mexico-oil-spill*, accessed on April 10, 2022.