Advances in Reliability, Safety and Security

ESREL 2024
Collection of Extended Abstracts

Hydro-Meteorological Conditions And Oil Spill Layer Thickness Impacts On Oil Spill Domain Movement At Baltic Sea Area

Ewa Dąbrowska

Department of Mathematics, Gdynia Maritime University, Morska St. 81-87, 81-225 Gdynia, Poland

Keywords: oil spill, hydro-meteorological conditions, oil spill layer thickness, probabilistic modelling, Baltic Sea

---

An original approach is presented to predicting oil spill domain movement and dispersion at the water surface. Special emphasis is placed on the impact of evolving hydro-meteorological conditions and the thickness of the oil spill layer. The main gap addressed by this study lies in the need for a comprehensive understanding of how changing environmental conditions and oil thickness interact to influence the movement and dispersion of oil slicks. By focusing on this aspect, this study aims to provide valuable insights into the complex dynamics of oil spill behaviour, enhancing the ability to predict and mitigate the environmental impacts of such incidents. Self-designed software was applied to develop and modify previously established mathematical probabilistic models for predicting changes in the shape of the oil trajectory.

First, a semi-Markov model of the process is constructed, and the oil thickness is analysed at the sea surface over time. Next, a stochastic-based procedure to forecast the movement and dispersion of an oil in diverse hydro-meteorological conditions considering a varying oil layer thickness is presented. This involves determining the trajectory and movement of a spill domain domain, which consists of an elliptical combination of domains undergoing temporal changes. By applying the procedure and program, a short-term forecast of the horizontal movement and dispersion of an oil slick provided its trajectory at the Baltic Sea within two days.

The complexity of the problem makes it challenging to predict the exact spread of an oil spill, and probabilistic modelling provides a useful framework for capturing this uncertainty. However, the rate at which an oil slick dissipates can vary depending on hydro-meteorological conditions and the oil volume discharged, as well as the other factors, like the presence of cleanup efforts and the type of oil and its physical properties and behaviour. Even if the real oil trajectories are a bit different from those determined by the proposed methods, they can still identify the hazardous area and make a significant contribution to the oil spill investigation. The research results can help responders understand the scope of the problem and mitigate the effects of environmental damage if the oil discharge reaches sensitive ecosystems.

Acknowledgements

This research was funded from the statutory activities of Gdynia Maritime University, grant number WN/PI/2024/03: “The influence of the oil layer thickness and the hydro-meteorological changes process on the movement of oil spills at sea”.

References

Bogalecka, M. 2019. Consequences of maritime critical infrastructure accidents with chemical releases. Int. J. Mar. Navig. Saf. Sea Transp. 13, 771–779.

Bogalecka, M. 2020. Consequences of Maritime Critical Infrastructure Accidents. Environmental Impacts. Modeling—Identification—Prediction—Optimization—Mitigation, Elsevier: Amsterdam, The Netherlands.

Bogalecka, M., Kołowrocki, K. 2018. Minimization of critical infrastructure accident losses of chemical releases impacted by climate-weather change. In Proceedings of the 2018 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), Bangkok, Thailand, 16–19 December 2018, 1657–1661.

Cordes, E.E., Jones, D.O.B., Schlacher, T.A., Amon, D.J., Bernardino, A.F., Brooke, S., Carney, R., DeLeo, D.M., Dunlop, K.M., Escobar-Briones, E.G., et al. 2016. Environmental impacts of the deep-water oil and gas industry: A review to guide management strategies. Front. Environ. Sci. 4, 58.

Dąbrowska, E. 2021. Conception of oil spill trajectory modelling: Karlskrona seaport area as an investigative example. In Proceedings of the 2021 5th International Conference on System Reliability and Safety (ICSRS), Palermo, Italy, 24–26 November 2021, Institute of Electrical and Electronics Engineers (IEEE): Piscataway, NJ, USA, 2021, 307–311.

Dąbrowska, E. 2022. Modelling oil spill layer thickness and hydro-meteorological conditions impacts on its domain movement at sea area. In Safety and Reliability of Systems and Processes, Summer Safety and Reliability Seminar, Krzysztof, K., Magdalena, B., Ewa, D., Beata, M.-M., Eds., Gdynia Maritime University: Gdynia, Poland, 51–64.

Dąbrowska, E. 2023. Oil discharge trajectory simulation at selected Baltic Sea waterway under variability of hydro-meteorological conditions. Water 15, 1957.

Dąbrowska, E. 2024. Numerical Modelling and Prediction of Oil Slick Dispersion and Horizontal Movement at Bornholm Basin in Baltic Sea. Water 16, 1088.

Dąbrowska, E., Kołowrocki, K. 2020. Monte Carlo simulation approach to determination of oil spill domains at port and sea waters areas. TransNav Int. J. Mar. Navig. Saf. Sea Transp. 14, 59–64.

Dąbrowska, E., Torbicki, M. 2024. Hydro-Meteorological Changes Forecast of Southern Baltic Sea. Water, 2024, 16(8), 1151.

Dobrzycka-Krahel, A., Bogalecka, M. 2022. The Baltic Sea under Anthropopressure—The Sea of Paradoxes. Water 14, 3772.

Eckroth, J.R., Madsen, M.M., Hoell, E. 2015. Dynamic modeling of oil spill cleanup operations. In Proceedings of the 38th AMOP Technical Seminar on Environmental Contamination and Response, Vancouver, BC, Canada, 2–4 June 2015, 16–35.

Fernandes, R., Necci, A., Krausmann, E. 2022. Model(s) for the Dispersion of Hazardous Substances in Floodwaters for RAPID-N, EUR 30968 EN, Publications Office of the European Union: Luxembourg, ISBN 978-92-76-46707-6.

Fingas, M. 2012. How to measure slick thickness (or not). In Proceedings of the 35th AMOP Technical Seminar on Environmental Contamination and Response, Vancouver, BC, Canada, 5–7 June 2012, 617–652.

Fingas, M. 2016. Oil Spill Science and Technology, 2nd ed., Elsevier: Amsterdam, The Netherlands.

Fingas, M. 2018. The challenges of remotely measuring oil slick thickness. Remote Sens. 10, 319.

Global Marine Oil Pollution Information Gateway. 2024. What Happens to Oil in the Water? Available online: http://oils.gpa.unep.org/facts/fate.htm (accessed on 1 February 2024).

Götz, M., Leichsenring, F., Kropp, T., Müller, P., Falk, T., Graf, W., Kaliske, M., Drossel, W.-G. 2018. Data Mining and Machine Learning Methods Applied to A Numerical Clinching Model. Computer Modeling in Engineering and Sciences 117, 387-423.

Guo, W., Wu, G., Jiang, M., Xu, T., Yang, Z., Xie, M., Chen, X. 2016. A modified probabilistic oil spill model and its application to the Dalian New Port accident. Ocean. Eng. 121, 291–300.

Huang, J.C. 1983. A review of the state-of-the-art of oil spill fate/behavior models. In Proceedings of the International Oil Spill Conference Proceedings, San Antonio, TX, USA, 28 February–3 March 1983, Volume 1983, 313–322.

Keramea, P., Spanoudaki, K., Zodiatis, G., Gikas, G., Sylaios, G. 2021. Oil spill modeling: A critical review on current trends, perspectives and challenges. J. Mar. Sci. Eng. 9, 181.

Kołowrocki, K., Soszyńska-Budny, J. 2011. Reliability and Safety of Complex Technical Systems and Processes: Modeling—Identification—Prediction—Optimization, 1st ed., Springer: London, UK.

Liu, H., Cai, J., Ong, Y.-S. 2017. An Adaptive Sampling Approach for Kriging Metamodeling by Maximizing Expected Prediction Error. Computers and Chemical Engineering 106, 171-182.

Magryta-Mut, B. 2023. Modeling safety of port and maritime transportation systems. Sci. J. Marit. Univ. Szczec. 74, 65–74.

Pietrucha-Urbanik, K., Rak, J. 2012. Water, resources, and resilience: Insights from Diverse Environmental Studies. Water 2023, 15, 3965.

Rutgersson, A., Kjellström, E., Haapala, J., Stendel, M., Danilovich, I., Drews, M., Jylhä, K., Kujala, P., Larsén, X.G., Halsnæs, K., et al. 2022. Natural hazards and extreme events in the Baltic Sea region. Earth Syst. Dyn. 13, 251–301.

Saçu, Ş., Şen, O., Erdik, T. 2021. A stochastic assessment for oil contamination probability: A case study of the Bosphorus. Ocean. Eng. 231, 109064.

Serafinska, A., Hassoun, N., Kaliske, M. 2016. Numerical optimization of wear performance – Utilizing a metamodel based friction law. Computers & Structures 165, 10-23.

Spaulding, M.L. 1989. A state-of-the-art review of oil spill trajectory and fate modeling. Oil Chem. Pollut. 4, 39–55.

Tchórzewska-Cieślak, B., Piegdoń, I. Matrix analysis of risk of interruptions in water supply in terms of consumer safety. J. Konbin 24, 125–140.

Torbicki, M. 2018. Longtime Prediction of Climate-Weather Change Influence on Critical Infrastructure Safety and Resilience. In Proceedings of the 2018 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), Bangkok, Thailand, 16–19 December 2018, 996–1000.

Yuriy, D., Dobrin, M. 2022. Oil spills weathering. Ann. Rev. Res. 8, 555730.