Available online at https://journal.rescollacomm.com/index.php/ijqrm/index

International Journal of Quantitative Research and Modeling

e-ISSN 2721-477X
p-ISSN 2722-5046

Vol. 4, No. 3, pp. 120-125, 2023

Numerical Modelling Techniques for Marine Debris : A Systematic Literature Review

Subiyanto[1*], Fenyawati Akhmad[1], Mohammad Fadhli Ahmad[3], Sudradjat Supian[4]

[1] *Department of Marine Science, Faculty of Fishery and Marine Science, Universitas Padjadjaran, Sumedang, Indonesia*
[2] *Faculty Ocean Engineering Technology and Informatics, Universiti Malaysia Terengganu, Kuala Terengganu, Malaysia*
[3] *Department of Mathematics, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran, Sumedang, Indonesia*

**Corresponding author email: subiyanto@unpad.ac.id*

Abstract

Currently, marine debris (MD) is one of them the most worrying global environmental problems because high impact on ecosystems, human health, and economy. One type of MD is that plastics have a significant and growing component, comprising between 60 - 80% of MD globally. Numerical model is an amalgamation of a large number of mathematical equations that rely on computers to find approximate solutions to underlying physical problems. Numerical modeling is key to understanding and determining the source, trajectory and fate of marine plastic debris (MPD). The purpose of this study is to review several methods that have been used in marine debris tracking modeling. The method used in this study is the PRISMA Method and Bibliometric Analysis.

Keywords: marine debris, modelling, bibliometric analysis

1. Introduction

The marine environment, encompassing vast oceans and coastal regions, plays a pivotal role in regulating global climate, supporting diverse ecosystems, and sustaining human livelihoods (Buonocore et al. 2021). However, this vital ecosystem faces an unprecedented challenge in the form of marine debris. Marine debris, consisting of both visible and microscopic particles of human-generated waste, has emerged as a significant environmental issue with far-reaching ecological, economic, and social implications. As the accumulation of marine debris continues to escalate, there is an urgent need for comprehensive strategies to mitigate its impact and manage its dispersion (Kandziora et al., 2019).

Marine Debris (MD) are all solid materials that are persistent, produced or processed, discarded, or abandoned in the marine and coastal environment. One type of MD is that plastics have a significant and growing component, comprising between 60 - 80% of MD globally (Purba et al. 2019). Currently, marine debris (MD) is one of them the most worrying global environmental problems because high impact on ecosystems, human health, and economy (Purba et al. 2021). In 2018, the Indonesian government has started a program: the National Marine Debris Action Plan, with a target of reducing 70% of marine plastic waste by 2025. Based on the results of a 2018 study, it is estimated that there are 0.27 to 0.59 million tonnes (MT) of marine plastic and debris in the local seas. Although, the target of reducing debris by 70% will be 0.35 MT per year, or a reduction of 29,500 tons of waste per month (Prabawa et al. 2021). Macro plastic is the largest of the three classification and consists of easy-to-see plastic naked eye. Examples include plastic bags, fishing nets, and water bottles (Chassignet, Xu, and Zavala-Romero 2021).

Scientific research has addressed many important aspects of the abundance, composition and dynamics of marine debris, and in particular plastic pollution (Maximenko et al. 2019). Numerical model is an amalgamation of a large number of mathematical equations that rely on computers to find approximate solutions to underlying physical problems. Numerical modeling is key to understanding and determining the source, trajectory and fate of marine plastic debris (MPD) (Jalón-Rojas, Wang, and Fredj 2019). The purpose of this study is to review several methods that have been used in marine debris tracking modeling

2. Materials and Methods

This section describes the process of this research: namely, the PRISMA method and bibliometric analysis.

2.1. The PRISMA Method

PRISMA is a procedure for producing articles that need to be studied through several selections process. This method is an analysis carried out to identify the elements of the article contained in a database. Studies on the review of several methods that have been used in marine debris modeling were traced through several databases, namely the Science Direct and the Dimension Database (apart from Science Direct). Articles were submitted using a search on Google Scholar with the keywords "Marine debris" or "method" or "cause" or AND "modeling". The search was conducted in English within the last twelve years (2010 to 2022).

Besides that, only articles in English and published as final peer-review were considered in the analysis. We got 8 articles from Dimensions and 14 articles from Science Direct. The selection process is by manual selection. First, select it to check if it exists is a duplicate of an article in the ScienceDirect and Dimension databases. This process aims to delete the same article. Furthermore, manual selection is a process to produce articles that are possible for thorough understanding. This process is divided into three steps that examine the relevance of the abstract, title, and keywords. Then, the accessibility of articles via the internet and the relevance of all articles to our research objectives were examined.

The selection of abstracts, titles, and keywords of articles that are relevant to the terms that have been determined produces 18 out of 22 articles. Next, we perform manual filtering by reading the full text. We comprehensively study all 18 articles to understand and selecting articles that are relevant to our criteria. Then obtained 10 articles that match the term for massive understanding. The selection process is shown in Figure 1.

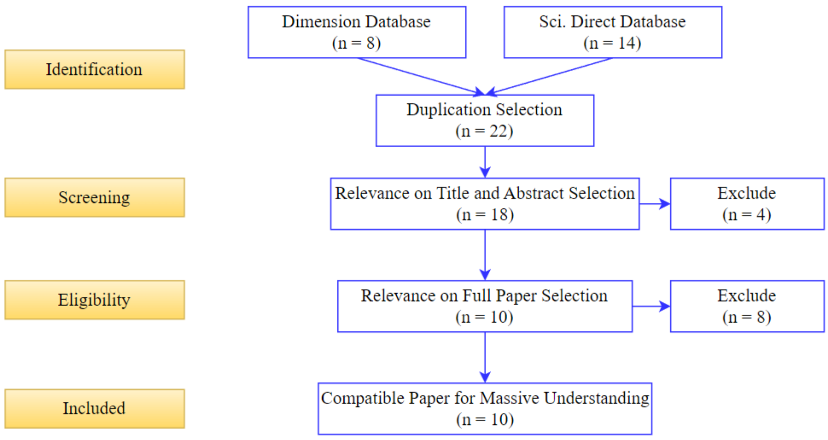

Figure 1: The flowchart of the selection process.

Figure 1 shows that several articles were excluded because of the relevance of the title and abstract. In case the paper has relevance to the title and abstract selection, we explain further information about why the article was excluded. First, all articles that pass the relevance of the title and the selection of abstracts are read thoroughly to determine relevance from the contents of the paper to the core topics to be discussed. In this selection process, we found that some articles don't contain the content we're looking for.

2.2. Bibliometric Analysis

A bibliometric analysis for the paper "Numerical Modelling Techniques for Marine Debris: A Systematic Literature Review" involves quantitatively examining the scholarly literature relevant to the topic. By analyzing bibliographic data, citation patterns, and publication trends, a bibliometric analysis provides insights into the impact, visibility, and evolution of research in this field. Bibliometric analysis was performed for the 10 articles in the dataset. This analysis this technique is often used for literature analysis to get a bibliographical view published scientific reports. Analysis can include keywords, national or subject bibliography, or other specific subject pattern. We got the result bibliometric analysis using the VOSViewer application. VOSviewer is a computer program that can be used to obtain maps of bibliometric analysis results.

3. Results and Discussion

In this section, we perfomed the result of the bibliometrics analysis by network visualization and the systematic literature review using the PRISMA method

3.1. Bibliometric Analysis Result

The result of bibliometric analysis were performed for one dataset, namely Dataset 1. It contained the article that passed the relevance on abstract and keywords selection

3.1.1. Visualization of the Occurance-Word Relation in Dataset 1

We search for the most frequently occurring words in all articles to get a word-occurrence analysis in Dataset 2. This dataset contains all articles aggregated based on the title, keywords, and abstract only. The VOSviewer application has supporting features to perform an event-word relationship assessment of the menu. We set a minimum number of keyword occurrences in an article once. Therefore, VOSviewer generates 42 words, which are selected as the word that has 50% of the most relevant terms. Words that cross the threshold are grouped in one. This shows that all words that cross the threshold have a strong relationship between them. The results show that the word that appears in Dataset 1 is "marine debris", "modelling", "beaching", "marine litter", dan "garbage patch", "lagrangian", "particle tracking", "plastic pollution", "forecasting system", "beach orientation", "marine", "wind drift coeficient", "dynamical properties", "global circulation", "lagrangian tracking model", "marine plastic debris", "oceanography", "sensitivity analysis", "wind shadow", "aggregation patterns", "floating marine debris", "lagrangian model" that appears 4 to 20 times. A visualization of the word-event network is shown in Figure 2

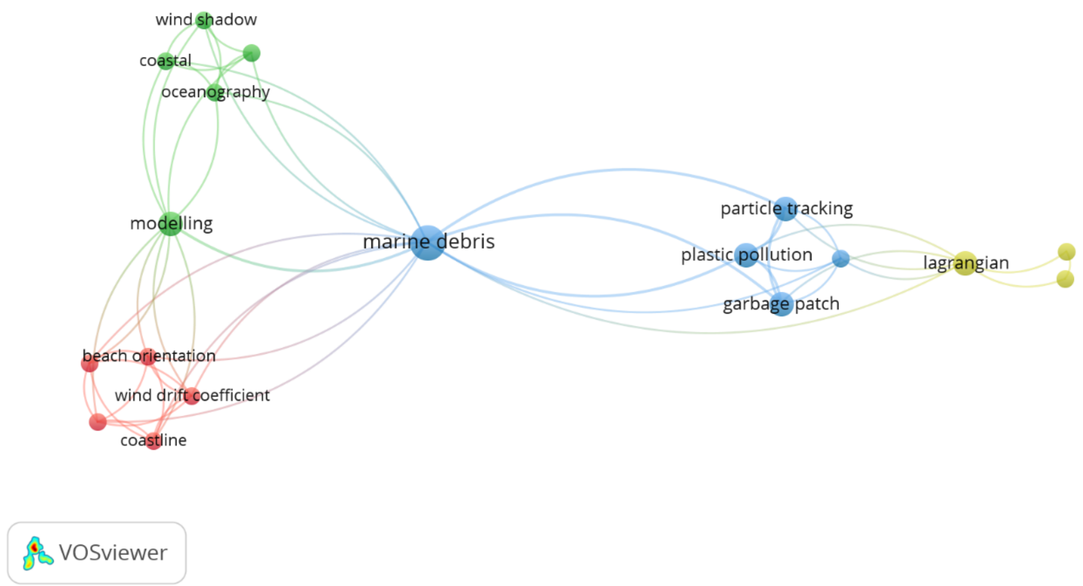

Figure 2: Visualization of word-event relation networks for Dataset 1.

3.2. Systematic Literature Review Results

All papers identified,including author, year published, cited by, model used, and whether they were analyzed numerically (see Table 1). The goal is to introduce the entire article and profit some basic information for further exploration

Table 1: Identification on Articles

(Name, Year)	Numerical Modelling	Method	References
(Yoon et al., 2010)	Yes	Reanalysis Data	(Yoon, Kawano, and Igawa 2010)
(Lebreton, Greer, and Borrero 2012)	Yes	Lagrangian particle tracking model	(Lebreton et al. 2012)

(Mansui et al., 2015)	Yes	OGCM	(Mansui, Molcard, and Ourmières 2015)
(Liubartseva et al., 2016)	Yes	Lagrangian model MEDSLIK II	(Liubartseva et al. 2016)
(Jalon-Rojas et al., 2019)	Yes	TrackMPD modelling	(Jalón-Rojas et al. 2019)
(Iskandar et al., 2021)	Yes	OGCM	(Iskandar et al. 2021)
(Critchell et al., 2015)	Yes	Advection-Dispersion model	(Critchell et al. 2015)
(Critchell et al., 2016)	Yes	Second-generation Louvain-la-Neuve Ice-ocean Model	(Critchell and Lambrechts 2016)
(Pareiro et al., 2019)	Yes	ROMS	(Pereiro, Souto, and Gago 2019)
(Maximenko & Hafner, 2018)	Yes	SCUD	(Maximenko and Hafner 2018)

The first article analyzes the characteristics of drift and beaching of floating marine litter in the Japan Sea numerically by means of data reanalysis. The horizontal position of marine litter as a particle is predicted by the following equations using a Lagrangian method. As a result, almost all litter beaches or flows out through straits within 3 years at most. The beaching characteristics also strongly depend on the buoyancy ratio. In the case with the lowest buoyancy ratio, litter mainly beaches along the Japanese coast with a maximum in Hokkaido (Yoon et al. 2010). The second article, The global ocean circulation model was combined with a Lagrangian particle tracking model to simulate 30 years of input, transport and accumulation of floating debris in the world's oceans. Using both terrestrial and maritime inputs, the modeling results clearly demonstrate the formation of five accumulation zones in the subtropical latitudes of the major ocean basins (Lebreton et al. 2012).

The third article explain model the transport of marine debris at sea level, virtual particles acting as Lagrangian tracers are introduced in the numerical circulation model. The simulation of drifting particles on the sea surface is carried out in two stages: first, the sea conditions and velocity fields are calculated with the appropriate general ocean circulation model (OGCM). Second, the virtual particle drift is calculated by the advection model using the calculated velocity field from the OGCM. The numerical simulations that have been used here allow us to describe possible accumulation scenarios and to quantify the possible coastal impacts of floating marine debris. The time scale referred to here is climatological, in the sense of 3 months to 1 year and the daily advection particle travel has been averaged 9 years, to highlight the presence or absence of permanent structures that can sustain floating objects for a long time. The variability of surface circulation is very high, and many of the instabilities that occur in the basin are well represented by the model figures (Mansui et al. 2015). The fourth article, the results of modeling the concentration of floating debris at sea level and on the shoreline in the Adriatic Basin during 2009-2015. The calculations are based on merging the input data of land and marine plastic waste with the Mark kov chain model which was built using the MEDSLIK-II Lagrangian model, using AFS ocean current simulation and ECMWF wind analysis. The Markov chain model provides significant computational flexibility and efficiency in simulating any configuration of on-site plastic waste, which is highly volatile. Not only does the Markov chain model enable forward-in-time plastic concentration simulations, it also provides the opportunity to properly perform backward-in-time simulations (Liubartseva et al. 2016).

The fifth article was explained about TrackMPD which is a three-dimensional non-Lagrangian particle tracking model of marine plastic waste transport in oceanic and coastal systems. TrackMPD's strength lies in its compatibility with a wide variety of streamline input formats, its expandability. TrackMPD can include windage, beaching, wash-off, degradation, biofouling, sinking and deposition. In particular, sinking and settling depend on the behavior of the particles (Jalón-Rojas et al. 2019). The sixth article is study in Jakarta Bay, garbage that ends up in Jakarta Bay has become an environmental problem. Understanding the path of marine debris in the oceans is important for identifying mitigation strategies. Prior to this study, the paths and sources of marine debris in Jakarta Bay were unknown. Using virtual floating marine debris particles in a high-resolution ocean model, the fate of marine debris based on the path of particles released in Jakarta Bay in forward and backward tracking experiments is analyzed. It was found that most of the particles from The Jakarta Bay flows towards the Indian Ocean in all seasons. They flow through the Sunda Strait and reach opened the Indian Ocean after a few weeks (Iskandar et al. 2021).

In the seventh article, research is conducted using hydrodynamics and advection-diffusion modeling to predict the fate of floating marine debris originating from urban rivers and ships, at scales relevant to GBRMP management and in topographically complex environments. Our results demonstrate the usefulness of advection-dispersion modeling in understanding marine debris movement and accumulation at relevant management scales (Critchell et al. 2015). The eighth article discusses the Louvain-la-Neuve Sea Ice model for evaluating the relative importance of coastal processes in movement of marine debris, sensitivity analysis was carried out using the second generation Louvain-la-Neuve Sea Ice Model. It is a depth-average, two-dimensional, finite element model with variable resolution developed by this model which is especially useful in shallow coastal zones with complex bathymetry and topography. This model allows for finer scaling of horizontal resolution and reduces the computational effort required to represent the entire model domain (Critchell and Lambrechts 2016).

The ninth article explained Regional Ocean Modeling System with Adaptive Grid Improvements in Fortran (ROMS-AGRIF v3.1.1) are used to calculate surface current fields. The model in this study was run for 4 years from 1 May 2012 to 30 April 2016. This analysis also indicates a seasonal inflow of floating debris into the southeastern Bay of Biscay, which will be greater during the winter. Both results - length of residence time and inclusion of floating debris - support the hypothesis that the Bay of Biscay can be considered a floating debris accumulation zone (Pereiro et al. 2019). The last article discussing SCUD (Surface Current from Diagnostics) is an empirical one the model, developed at IPRC/UH, was enforced with data from satellite altimetry and scatterometry, and calibrated at a 1/4° global network uses satellite tracked paths floating buoys (Maximenko and Hafner, 2010). Model calculate particle trajectory and tracer evolution density, was released on March 11, 2011 along the east coast from Honshu, Japan (Maximenko and Hafner 2018).

4. Conclussion

Marine debris (MD) is one of them the most worrying global environmental problems because high impact on ecosystems, human health, and economy. The method used in this study is the PRISMA Method and Bibliometric Analysis. There are 10 articles reviewed in this study. There are several model that used on the article which are Reanalysis data, Lagrangian particle tracking model, ODCM, Lagrangian model MEDSLIK II, Track MPD, Advection-Dispersion model, Second-generation Louvain-la-Neuve Ice-ocean Model, ROMS, SCUD.

Acknowledgments

The author would like to thank the Dean of the Faculty of Fishery and Marine Science and the Directorate of Research and Community Service (DRPM), Universitas Padjadjaran for support this work. The author also thanks the National Research and Innovation Agency of Indonesia (BRIN) for provide Postdoctoral program.

References

Buonocore, E., Grande, U., Franzese, P. P., & Russo, G. F. (2021). Trends and evolution in the concept of marine ecosystem services: An overview. Water (Switzerland), 13(15), 1–14. https://doi.org/10.3390/w13152060

Chassignet, E. P., Xu, X., & Zavala-Romero, O. (2021). Tracking Marine Litter With a Global Ocean Model: Where Does It Go? Where Does It Come From? Frontiers in Marine Science, 8(April), 1–15. https://doi.org/10.3389/fmars.2021.667591

Critchell, K., Grech, A., Schlaefer, J., Andutta, F. P., Lambrechts, J., Wolanski, E., & Hamann, M. (2015). Modelling the fate of marine debris along a complex shoreline: Lessons from the Great Barrier Reef. Estuarine, Coastal and Shelf Science, 167, 414–426. https://doi.org/10.1016/j.ecss.2015.10.018

Critchell, Kay, & Lambrechts, J. (2016). Modelling accumulation of marine plastics in the coastal zone; what are the dominant physical processes? Estuarine, Coastal and Shelf Science, 171, 111–122. https://doi.org/10.1016/j.ecss.2016.01.036

Iskandar, M. R., Surinati, D., Cordova, M. R., & Siong, K. (2021). Pathways of floating marine debris in Jakarta Bay, Indonesia. Marine Pollution Bulletin, 169(March), 112511. https://doi.org/10.1016/j.marpolbul.2021.112511

Kandziora, J. H., van Toulon, N., Sobral, P., Taylor, H. L., Ribbink, A. J., Jambeck, J. R., & Werner, S. (2019). The important role of marine debris networks to prevent and reduce ocean plastic pollution. Marine Pollution Bulletin, 141(July 2018), 657–662. https://doi.org/10.1016/j.marpolbul.2019.01.034

Jalón-Rojas, I., Wang, X. H., & Fredj, E. (2019). A 3D numerical model to Track Marine Plastic Debris (TrackMPD): Sensitivity of microplastic trajectories and fates to particle dynamical properties and physical processes. Marine Pollution Bulletin, 141(September 2018), 256–272. https://doi.org/10.1016/j.marpolbul.2019.02.052

Lebreton, L. C. M., Greer, S. D., & Borrero, J. C. (2012). Numerical modelling of floating debris in the world's oceans. Marine Pollution Bulletin, 64(3), 653–661. https://doi.org/10.1016/j.marpolbul.2011.10.027

Liubartseva, S., Coppini, G., Lecci, R., & Creti, S. (2016). Regional approach to modeling the transport of floating plastic debris in the Adriatic Sea. Marine Pollution Bulletin, 103(1–2), 115–127. https://doi.org/10.1016/j.marpolbul.2015.12.031

Mansui, J., Molcard, A., & Ourmières, Y. (2015). Modelling the transport and accumulation of floating marine debris in the Mediterranean basin. Marine Pollution Bulletin, 91(1), 249–257. https://doi.org/10.1016/j.marpolbul.2014.11.037

Maximenko, N. A., & Hafner, J. (2018). Numerical modeling of drift of marine debris, generated by the 2011 tsunami in the eastern Japan. 23(2), 234–237. https://doi.org/10.29006/978-5-9901449-4-1-2018-65

Maximenko, N., Corradi, P., Law, K. L., Sebille, E. Van, Garaba, S. P., Lampitt, R. S., Galgani, F., Martinez-Vicente, V., Goddijn-Murphy, L., Veiga, J. M., Thompson, R. C., Maes, C., Moller, D., Löscher, C. R., Addamo, A. M., Lamson, M., Centurioni, L. R., Posth, N., Lumpkin, R., … Wilcox, C. (2019). Towards the integrated marine debris observing system. Frontiers in Marine Science, 6(JUL). https://doi.org/10.3389/fmars.2019.00447

Pereiro, D., Souto, C., & Gago, J. (2019). Dynamics of floating marine debris in the northern Iberian waters: A model approach. Journal of Sea Research, 144(October 2018), 57–66. https://doi.org/10.1016/j.seares.2018.11.007

Prabawa, F. Y., Adi, N. S., Pranowo, W. S., Sukoraharjo, S. S., Gautama, B. G., & Suhelmi, I. R. (2021). Strategy on marine debris reduction in Indonesia: A review and recommendation. IOP Conference Series: Earth and Environmental Science, 925(1). https://doi.org/10.1088/1755-1315/925/1/012027

Purba, N. P., Faizal, I., Cordova, M. R., Abimanyu, A., Afandi, N. K. A., Indriawan, D., & Khan, A. M. A. (2021). Marine Debris Pathway Across Indonesian Boundary Seas. Journal of Ecological Engineering, 22(3), 82–98. https://doi.org/10.12911/22998993/132428

Purba, N. P., Handyman, D. I. W., Pribadi, T. D., Syakti, A. D., Pranowo, W. S., Harvey, A., & Ihsan, Y. N. (2019). Marine debris in Indonesia: A review of research and status. Marine Pollution Bulletin, 146(May), 134–144. https://doi.org/10.1016/j.marpolbul.2019.05.057

Yoon, J. H., Kawano, S., & Igawa, S. (2010). Modeling of marine litter drift and beaching in the Japan Sea. Marine Pollution Bulletin, 60(3), 448–463. https://doi.org/10.1016/j.marpolbul.2009.09.033