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Alternatives Technologies for Marine-Coastal Environment Debris Monitoring: A Review

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Abstract: The marine and coastal environment problems have aroused the attention of many countries in the world. It is estimated that eight million tons of debris find their way into the world's oceans, thus disturbing aquatic and marine ecosystems every year. Particularly in the case of coastlines, many studies show that most marine litter (60-80%) consists of plastic. **Objectives:** This work aims to provide the bibliometric mapping and analysis of the technology used in marine and coastal debris monitoring over the last decades and the critical issues concerning marine environment waste monitoring. **Method and results:** This study created a bibliometric profile from the google scholar publication database related to the research objectives from 2010 to 2021, then analyzed it using the software programs. The results of this study show a clear picture of the types of technology that have been widely used and relevant to marine debris monitoring, specifically IoT, sensor, drone, Unmanned Aerial Vehicle (UAV), Remotely Operated Vehicle (ROV), Satellite, Wireless Sensor Network (WSN), and mobile communication network. However, the consideration of this technology-based should fit with the requirement of the monitoring area, whether for The space, surface, mid-water, or seabed area. **Conclusion:** In the last decades, the IoT, sensors, drones, ROVs, satellites, WSN, and mobile communication network-related technologies have been widely regarded as alternative technologies for marine debris monitoring. However, an integrated technical solution is required to support any possible combination of protocols and technologies.

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1 Introduction

Seventy percent of the earth's surface area is covered by oceans, including lakes, mudflats, coasts, and deep oceans. The marine environment gives us a significant impact on ecosystems, plays an essential role in local and global climate, and contributes to climate change throughout the year. Due to the lack of human awareness in protecting marine ecosystems, decades of pollution, and unplanned coastal development, the oceans face marine and nutritional pollution, climate change, and resource depletion threats. These threats significantly impact environmental systems, such as biodiversity and natural infrastructure, while creating health, safety, and global financial risks.

According to [1],*marine debris* is defined as "any anthropogenic, manufactured, or processed solid material (regardless of size) discarded, disposed of, or abandoned in the marine environment, including all materials discarded into the sea, on the shore, or brought indirectly to the sea by rivers, sewage, stormwater, waves, or winds." Every year, the growth of marine debris is increasing, and it easily flows across borders.

Even in remote areas far away from human contact, they are also polluted by marine debris. Disposing of large amounts of solid waste that is disproportionate to nature's ability to dispose of waste will result in a significant increase in marine debris, whether found on the surface, floating in the sea, or on the seabed, even on the beach. This will eventually cause economic, human health, environmental and aesthetic issues and bring complex, multi-dimensional challenges.

Many research results and official reports indicate that this increase in marine debris will continue for a long time. According to [2], plastic production has increased by 22 times in the past 50 years, and in 2015, the global plastic recycling rate was only 9%. High-demand plastic products, unmanaged plastic waste, and plastic waste that do not comply with proper waste management regulations are increasingly threatening the marine environment. Millions of tons of plastic from land end up entering the marine environment every year.

Targets related to marine debris have been defined in the United Nations Sustainable Development Goals (SDG target 14.1) and United Nations Environment Assembly Resolution (UNEA) documents. It emphasizes the importance of global attention to solve this ocean plastic problem. The sustainable development of target 14.1 recognizes the need for consistent monitoring and reporting of marine debris, which states that by 2025, all types of marine pollution should be prevented and significantly reduced [5]. In the Sustainable Development Goal indicator 14.1.1b that specifically discusses "plastic waste," plastic waste is divided into four core sub-indicators [3]: (1) Plastic waste is washed/stored on the beach (beach waste); (2) Plastic garbage and debris floating in the water column; (3) Plastic garbage on the seabed/seabed; (4) Plastic ingested by biota (such as seabirds) (optional).

Currently, the problems in overcoming the issues in marine debris are the difficulties in predicting how much marine debris is generated. The scattered debris will eventually stay and remain on the coast and in the ocean. Most data still use hypothesis-based methods. Due to the lack of a systematic monitoring mechanism globally, it is almost impossible to provide accurate measurement results. In addition, the lack of systematic monitoring of the sources, patterns, and distribution of plastic waste that ultimately enters the marine environment has resulted in a global lack of preventive mechanisms. This data uncertainty and lack of substantive monitoring emphasize the urgent need for better observations. From the above data, it can be seen that the garbage problem in coastal and sea areas is an urgent problem to be solved. However, this problem will be challenging because the data related to the generation of waste flowing into the ocean is dynamic data, which moves every day, depending on the waste generated.

There have been many studies discussing various alternative technologies that can be used to monitor waste in the sea and beaches. However, as this research is conducted, none of the existing literature has discussed the mapping of technologies with marine debris monitoring layers. Figure 1 illustrates the existing problem of plastic litters pathway arrived at the ocean, such as waste that comes as direct discharge at the coastline, floating debris waste that sinks and end to the seafloor. Thus, this study aims to provide the bibliometric mapping and analysis of the technology used in marine and coastal debris monitoring, especially in the studies done over the last decades and the critical issues concerning marine environment waste monitoring. Through this article, the authors summarize several related studies that have been produced, thereby providing comprehensive information with an emphasis on technology-based solutions for handling waste problems in coastal and marine areas.

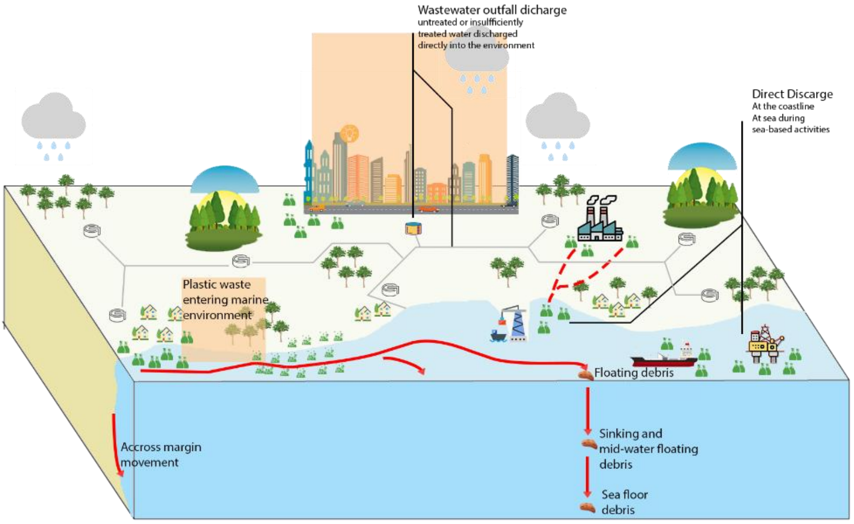

Fig.1. Pathways of plastic litter into the ocean as adapted from [4]

2 Method

Most of the information about plastic pollution in coastal and marine areas can be found on Internet resources and discussed from different angles. Several research results related to using the latest technology to prevent and overcome these problems can be described from existing scientific journals. The reference search focuses on journal articles related to marine debris or issues from 2010-2021.

The initial step in conducting the research is to seek the critical issue regarding the phenomenon in the marine environment ecosystem specifically related to pollution and waste monitoring. Figure 2 highlights the critical steps in conducting the research. Steps 1 until 4 will be discussed in this section, while the remaining steps will be discussed in the next section.

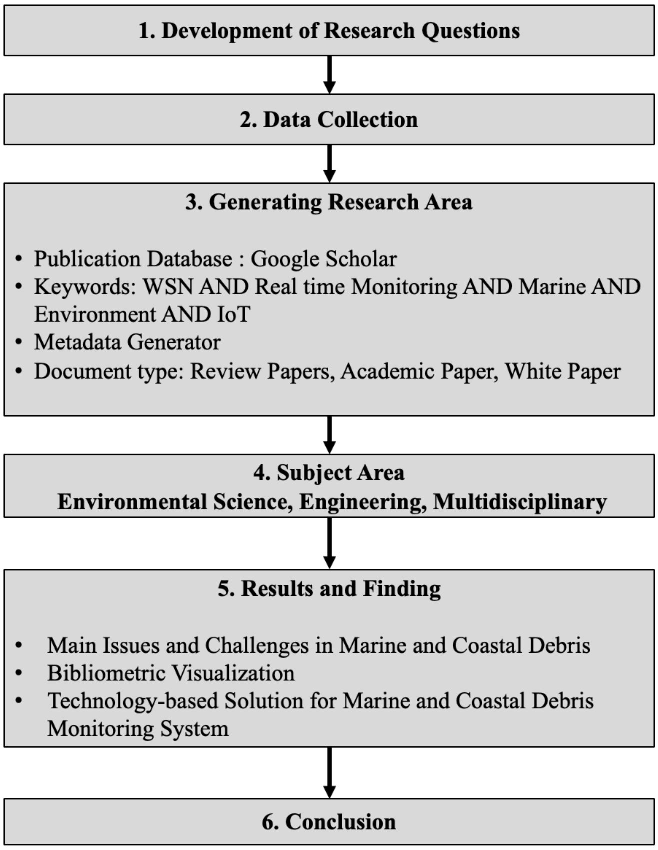

Fig. 2. Methodology of the Bibliography for Marine Debris Technology-Based Monitoring.

The first step is to develop the research question to identify issues associated with the topic and the known challenges. Afterward, the second step is to perform data collection, which has been done through in-depth literature collection using Google Scholar search. As the third step, additional information was taken from several project implementation reports, review and academic papers, as well as white paper that contains data related to this research. Moreover, as part of step four, the authors complement and deepen the discussion on selected subject areas: environmental science, engineering, and multidisciplinary. This section analyzes literature taken from scientific journals that relate to the latest technologies used to reduce the amount of plastic waste in the oceans and coastal areas.

A study released in 2016 promotes awareness that Author in [5] stated that debris in the marine environment affects at least three effects towards life in the marine environment: plastic ingestion, entanglement, and its chemical reaction. The plastic waste debris could be found in surrounding areas all over water bodies, such as on the ocean's surface, in specific depths of the ocean, and the seafloor. Additionally, the waste debris could be found on beaches and coastlines.

The researcher conducted the implementation of a tagging system using a small device known as "Marine-Skin." The device is implemented directly in the marine environment skin (some of the mentioned is fish skin) to sustain harsh environments in the sea to monitor conductivity, temperature, and depth. This research presents the variance of IoT, which works well underwater. This research has not fully mentioned the interactive mechanism system (such as sending and receiving) [6]. Works in caters to the essential needs for Marine Environment Monitoring, (i) high water resistance, (ii) strong robustness in hardware, (iii) low energy consumption and the ability for energy harvesting, as well as (iv) stability of radio signal. Looking at the area of monitoring, the device could easily sway and lose its reachability, and communication needs to be effectively maintained with the proper topology [7].

Pollution in the marine environment accumulated and thus drifted across the ocean. Factual information gathered from the higher view, such as satellite view, gives crucial insight in understanding and identifying plastic waste debris pollution and its movement. The investigation and experiment analysis conducted in [8] highlight the work on the observed ocean surface from space, which is also able to observe the prediction from the possible surface debris movement, thus predicting debris concentration point. The satellite monitoring is able to serve as guidance on a bigger monitoring scale as well as help the researcher in understanding the large-scale surface of the ocean.

A Study in [9] mentioned the composition of The Ocean of Things (OoT) which could include the life on the land (offshore) as well as the underwater as well, which is crucial to monitor the marine environment in both ecosystems since debris can be found at both areas. This study highlights at least five challenges in IoT for conducting OoT, which this study has observed for over five years in two different oceans. The research observed that the OoT challenges are Propagation Speed (Delay), Reliability, Transmission Rate, Battery (Energy), and Mobility.

The discussion above reports that many studies have raised the problem of plastic waste on the coast and the sea. Some of them focus on observation from the point of view of technology, which results in comprehensive scientific journals that are discussed separately. To map out some of these discussions, the following are the results of observations related to the technology that has been discussed, taking into account several indicators of discussion that focus on: (1) Management of plastic waste being washed/deposited on the beach or shoreline (beach waste); (2) Management of plastic waste in the water column; (3) Handling plastic waste in rivers and estuaries; (4) Management of plastic waste from marine activities (shipping, fishing, mining); (5) Management of plastic waste that flows into the sea due to coastal disasters.

The topic of marine debris monitoring has gained researcher attention, especially those related to coastal and marine waste monitoring pollution. The preliminary work carried out in Figure 2, specifically in step 1 until step 4, highlights the critical steps in conducting research, leading to identifying problems and challenges related to the topic. Further observations are made regarding research that focuses on implementing technology for coastal and marine waste monitoring from the research questions above. The remaining step is to look into results and findings intensively, which consist of central issues and challenges in marine and coastal debris, bibliometric visualization, and technology-based solution for marine and coastal debris monitoring systems elaborated in section 4.

4 Results and Discussion

4.1 Main Issues in Marine and Coastal Debris

According to [10], plastics are the most abundant and persistent type of litter found in the marine environment. Plastic is made up of molecules, the tiny particles that make up the substance and are always composed of large polymers. Plastics come in various shapes and sizes. There are soft and flexible plastics and very hard plastics that are almost as strong as metal that can be obtained by modifying the production process [11]. The characteristics of plastic in the form of delicacy, toughness, quality, minimal effort to create, and adaptability to utilization have resulted in plastic equipment dominating our lives. Plastics are integrated into almost everything that humans produce.

The plastic components that enter the environment as plastic waste will not decompose quickly, and it will take hundreds of years to degrade into micro plastics and nano plastics through physical, chemical, and biological processes. [12]. When they end up in the oceans, they directly affect the life of marine organisms, especially mammals, birds, and fish. Much of this plastic waste flows through the air and water and ends up in the ocean. Rivers become a source that contributes to waste, which pollutes the marine environment, estimated 90% of the global river wastes are attributable to the top 10 rivers [13].

In addition, human activities in marine areas are also partly responsible for the flow of plastic and waste into the ocean. According to [14] , abandoned fishing gear accounts for 46% of the plastic currently in the oceans. Ocean pollution is a serious global problem. Millions of tons of waste eventually flow into the ocean every year, causing various environmental, economic, health, and aesthetic problems, and have severe impacts. This fact exacerbates this problem. If this trend continues, it is estimated that approximately 12,000 metric tons of plastic waste will end up in landfills or the natural environment by 2050 [15].

4.2 Challenges in Marine and Coastal Debris

The vast marine environment makes marine debris monitoring systems quite challenging. Not only related to problems that appear on the surface, coastal and marine monitoring is expected to monitor water conditions above the water surface. Most of the trash found on the ground, ocean, or beach is scattered about one meter in size and less than one meter in size. It is difficult to image from existing space platforms with a limited resolution of 5 m to 1 km. It is different from plastic that is covered by the surface of the water around it. Fragmentation and reduced decomposition also limit the possibility of debris being detected by the imager.

The fact is that these sizeable remote sensing instruments cannot directly detect plastics. It is due to the size and resolution of plastic components compared to the resolution and the limited capabilities of high-resolution systems such as optical sensors and radars [16]. In terms of detecting objects in the depths of the sea, monitoring becomes much more complicated where there are changes that affect detection where the more profound the sea level, the less lighting, the darker the environment, and the higher the water pressure.

It can be seen that each marine debris problem requires a different approach and solution. For example, a monitoring system that supports an air system offers a higher spatial resolution but has limitations in terms of spatial. Ground-based monitoring systems such as HF radar can monitor debris objects floating on the surface but not see small plastic debris. It is clear that regardless of the type of application, an integrated technology solution is needed, either sensor, communication devices, transfer of data packets from client devices to servers with the help of appropriate application protocols, or a combination of several technologies. For example, the development of Industry 4.0 technology, specifically unmanned aerial vehicles (Unmanned Aerial Vehicles), Internet of Things (IoT), and sensor technology, combined with the proposed technical system, are able to collect, analyze and present data through a cloud-based software service platform that all system users and stakeholders can use.

4.3 Solution for Marine and Coastal Debris Monitoring System

Bibliometric is a systematic way to model a quantitative result. Results from the bibliometric mapping of marine debris monitoring and its technological implementation as illustrated in Figure 3 and Figure 4. The generated data used in the bibliometric are selected from recent decades.

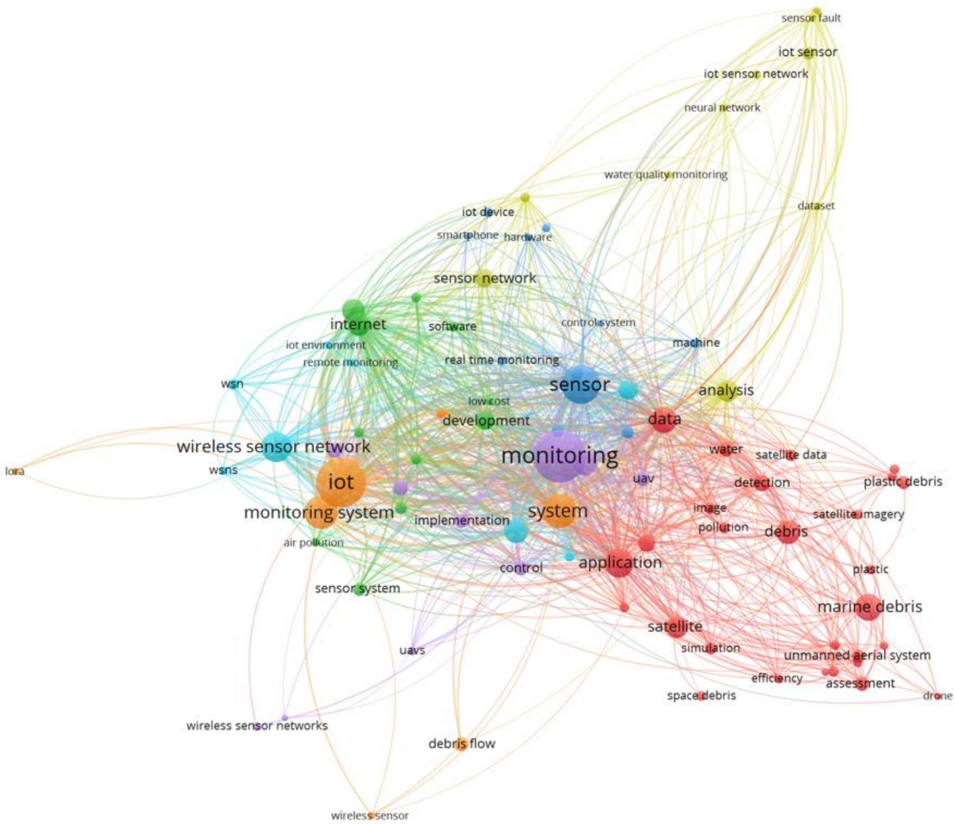

Fig. 3. Correlated research in the umbrella term of Marine Debris Monitoring Technology-based

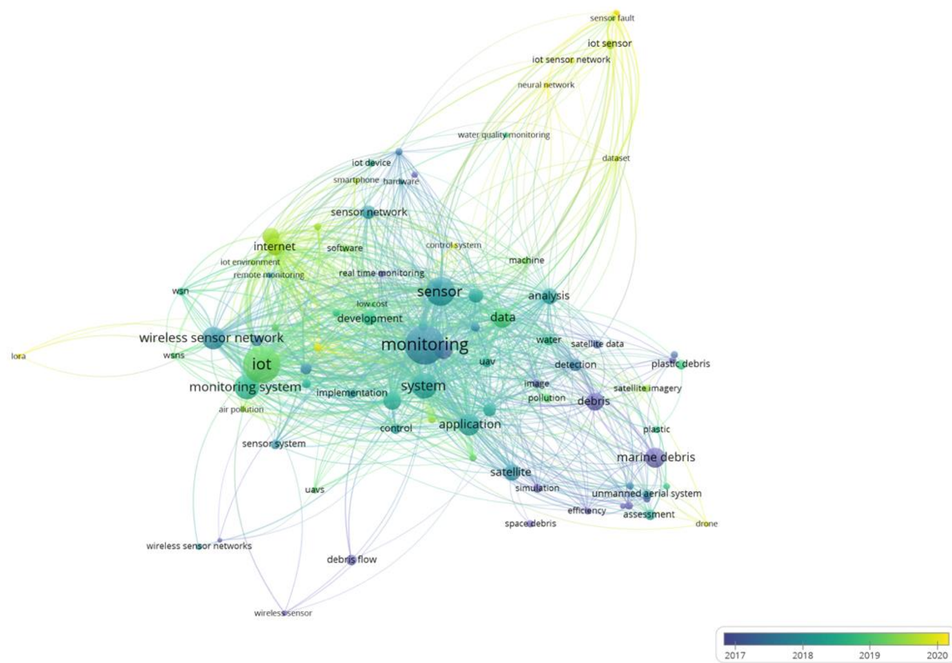

Fig. 4. The development of research trends under the umbrella term for Marine Debris Monitoring Technology-based from recent decades.

The results of bibliometric reveal that the various technology that often highlighted in the recent research of marine debris monitoring are Internet of Things (IoT), sensor, drone, Unmanned Aerial Vehicle (UAV), Remotely Operated Vehicle (ROV), satellite, Wireless Sensor Network (WSN), and mobile communication network. These various technologies are applied in the five-layer architecture of technologies adaptation for marine debris monitoring, as highlighted in Figure 5.

From the bottom to the upper layer, starting from the perception layer, sensors and actuators are becoming the underlying technologies to detect, command, and perform its intended function in their environments. The data transmission layer functions as the intermediary layer between the perception layer and the data collection layer, where the wireless sensor network and mobile communication network play a major role to ensure the perceived data are able to be transmitted and stored at the data collection layer.

At the data collection layer, captured data are pooled and categorized for application-layer monitoring. The application layer monitoring is divided into four categories. The first category cares for space/aerial to enable monitoring from space view through satellite technology. Second, surface / floating to facilitate monitoring conducted from the surface and non-underwater area by buoy-based monitoring.

Third, the mid-water monitoring assisted by Unmanned Aerial Vehicle (UAV) allows monitoring further to areas where the space and surface / floating sensors cannot reach; the UAV will float in the mid-water located between the surface seabed areas. Last, seabed/sea bottom is the most challenging area to reach; however, estimated that all debris fall in the sea will sink to the seabed. Hence, monitoring in seabed/sea bottom areas is the most vital and the most challenging. Remotely Operated Vehicle (ROV) is able to support the operation in the seabed/sea bottom monitoring.

The business layer manages the data from the categorized application layer into a report analysis and supports graphic representations of the monitoring information. The business layer is essential in accommodating more meaningful information retrieved as the result of the end-to-end monitoring process.

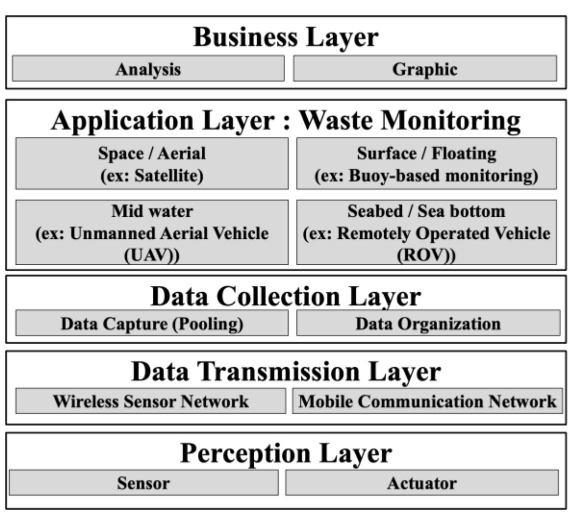

Fig. 5. Five Layer Architecture of Technologies Adaptation for Marine Debris Monitoring

5 Conclusions

This study shows that waste in coastal and marine areas is a problem that needs to be solved immediately. The data relating to the generation of waste flowing into the ocean is dynamic, moving every day, depending on the generated waste, accumulates and drifts across the ocean. A large amount of information is collected from many different views of the multi-layered sea to understand and identify the pollution movement of plastic waste debris. The space/aerial enabled through satellite technology, surface / floating facilitated by buoy-based monitoring, the mid-water monitoring assisted by Unmanned Aerial Vehicle (UAV), and the seabed/sea bottom through Remotely Operated Vehicle (ROV). Regardless of the type of application mentioned, an integrated technical solution is required to support any possible combination of protocol and technology.

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