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Perspective

A limiting integrative effort plastic waste in the sea of Indonesia and China: The Penta Helix model perspective

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Abstract: Indonesia ranks as the second-largest source of plastic garbage in marine areas, behind China. This is a critical problem that emphasises the need for synergistic endeavors to safeguard the long-term viability of marine ecosystems. The objective of this work is to examine the implementation of the Penta Helix model in the management of marine plastic trash. For this purpose, a Systematic Literature Review (SLR) was carried out, utilizing scholarly papers sourced from the Science Direct, Scopus, and Web of Science databases. The analysis centred on evaluating the Penta Helix model as a cooperative framework for tackling plastic waste management in the marine environments of Indonesia and China. The results suggest that the Penta Helix methodology successfully enables the amalgamation of many interests and resources, making a valuable contribution to the mitigation of plastic pollution in the waters of both nations. In order to advance a more comprehensive and sustainable approach to plastic waste management, this multidisciplinary plan brings together stakeholders from government, academia, business, civil society, and the media. Under this framework, the government is responsible for formulating laws, guidelines, and programs to decrease the use of disposable plastics and improve waste management infrastructure, all while guaranteeing adherence to environmental constraints. Simultaneously, the industrial and academic sectors are responsible for creating sustainable technology and pioneering business strategies, while civil society, in collaboration with the media, has a crucial role in increasing public consciousness regarding the destructive effects of plastic trash. This comprehensive strategy emphasizes the need of synergistic endeavors in tackling the intricate issues of marine plastic contamination.

Keywords: plastic waste; Penta Helix model; integratif effort; environmental sustainability

1. Introduction

Currently, there is a transnational problem with marine plastic litter that has to be addressed by many countries and parties (Löhr et al., 2017). Plastics are being used more often in people's daily lives for a wider range of applications (Royer et al., 2018), because it is seen to be a material that is more accessible, lighter, more durable, and less expensive for a variety of uses, plastic is increasingly becoming the material of choice for many people. Plastic is regarded as the marine waste kind that poses the greatest threat to marine life and the environment. Plastic waste in the ocean is a threat to maritime security, considering that studies of plastic waste can pollute marine ecosystems or threaten human health and the economy in the marine sector (Abalansa et al., 2020).

Globally, countries have concerns about plastic's risks and possible side effects if it is not managed correctly. According to earlier study, six out of the eleven

Southeast Asian nations are in the top 20 nations in the world for improperly managing their plastic garbage (Geyer et al., 2017). According to other research results, population density, improper waste management, and production per nation are the leading causes of the 1.15 to 2.41 million tonnes of plastic garbage that flow annually from rivers to the sea (Lebreton et al., 2017). In 2018, a World Bank report noted that the projected plastic waste in the oceans reached 150 million tons (Kibria et al., 2023). A total of 192 coastal countries, China, Indonesia, the Philippines, Vietnam, and Thailand, have the highest level of productivity in producing the world's most significant waste, which exceeds half of the total plastic waste in the ocean (Zahrah et al., 2024).

Indonesia is the second-largest producer of marine plastic pollution, which is another concern for the entire world (Jambeck et al., 2017). According a research made by the Indonesia National Plastic Action Partnership (NPAP), 4.8 million tons (or 70%) of all the plastic garbage in Indonesia needs to be managed. All 0.62 million tons (9%) of unchecked plastic waste, according to end up in Indonesian rivers and seas. 0.27 to 0.60 million tons of plastic garbage enter Indonesian waterways annually, according to pertinent statistics published by the Indonesian Institute of Sciences (LIPI) (Kamaruddin et al., 2022). This plastic waste crisis is deeply rooted in Indonesia's socio-economic context, where rapid urbanization and inadequate waste management infrastructure contribute to the problem. Many regions lack the resources and systems necessary to address waste effectively, leading to significant environmental degradation. Politically, while there have been initiatives to tackle plastic pollution, implementation often falls short due to inconsistent enforcement and local governance challenges. In contrast, China, as a major producer of plastic, faces its own complexities, including a massive consumption rate and a recycling industry that has been impacted by recent international restrictions. Both countries must confront these intricate socio-economic and political factors to develop comprehensive strategies for mitigating plastic waste and protecting their environments.

Meanwhile, the recycling rate of waste in Indonesia, which is mainly in the informal sector, is less than 5% of the waste generated and a plastic recycling rate of only 7% (Widyatmika and Bolia, 2023). The fact is that most of the plastic recycling industry is available in the western islands, such as Java and Sumatra. However, plastic waste contributes around 10.6% of the total national waste generation (Maitlo et al., 2022). The existence of plastic waste flowing into the Indonesian Sea needs to be addressed because it is cross-border: ocean currents will carry waste to remote islands. In northern Indonesia, areas significantly affected by marine debris include the Riau Archipelago, West Kalimantan, East Kalimantan, North Maluku, and Raja Ampat. The southern part is Aru Island, Babar Island, Sumba, Bali, and the west coast of Java Island. Marine debris has spread to Malaysia, Timor Leste, Brunei Darussalam, Thailand, and Australia, not only within the scope of the Indonesian state (Dobler et al., 2022).

In China, more than 3000 registered businesses that handled and processed plastic garbage in 2019 were supported by the government. More than 10,000 tonnes of recycled plastic may be processed annually by 300 separate businesses, 50 of which can process more than 50,000 tonnes. (Liu and Liu, 2023). Nonetheless, China possesses the infrastructure needed to annually repair almost 6,000,000 tonnes of

plastic garbage. The vast bulk of China's plastic recycling markets are located in the provinces of Zhejiang, Jiangsu, Shandong, Hebei, and Liaoning. These markets also serve as areas where trash is processed or distributed. A recovery and processing cluster has emerged in the plastic recycling industry as a result of more centralized transactions (Yoshida, 2022). Although the opportunities for plastic recovery, recycling, and regeneration have grown due to increased domestic and international attention to pollution from plastic waste, China's plastic recycling industry still faces several difficulties (Pilapitiya and Ratnayake, 2024).

The global cumulative stock of plastic waste that is inadequately managed is predicted to increase from 61–72 million metric tons (MT) in 1990 to 5109–5678 MT by 2050. Four scenario analyses told different stories: The business-as-usual (BAU) scenario, mitigation scenario 1: Capping GDP, mitigation scenario 2: Extending education, and mitigation scenario 3: Fighting corruption (Zhang and Liu, 2018). Indonesia and China are collaborating to achieve comprehensive and mutually beneficial solutions to plastic pollution. These initiatives include international cooperation aimed at reducing plastic waste, collaboration in marine language education, and engagement of the public society in plastic waste management. Additionally, the two countries are implementing national regulations and circular economic policies to reduce plastic waste and optimize environmental management strategies. Using the Helix model, various stakeholders can work together to reduce plastic pollution and optimize environmental management strategies in both countries.

Based on the description and the problems mentioned above, collaboration with the Penta Helix model is needed as an integrated action in managing plastic waste with various stakeholders to combat plastic waste in the oceans of Indonesia and China. In Indonesia, in environmental control, the Penta Helix collaboration has been implemented (Amrial et al., 2017). Previously, the triple helix collaboration in waste management had been implemented. However, results show that there are still problems and solutions that still needed to be given boundaries and provided a standard arena for dialogue (Rosenlund et al., 2017). Although the triple helix model has many obstacles, the government still applies it to waste innovation policies to achieve more systemic changes (Anttonen et al., 2018).

In order to address environmental issues, particularly the management of plastic trash, this study used the research findings of Rosenlund et al. (2017), Anttonen et al. (2018) and Amrial et al. (2017). The Penta Helix model is to empower local, regional, and national authorities and find innovative, cost-effective approaches to developing, implementing, and improving sustainable energy and action plans (Capetillo et al., 2021). The acronym ABCGM (Karnawijaya et al., 2022; Muhyi et al., 2017; Zubaidah et al., 2023), and the word "Penta Helix" are commonly used in Indonesia to refer to academics, business, community, government, and the popular media. To enhance the creation and execution of an activity, the major goal is to create a penta-helix-based technique, include and assist authorities at all levels, and work with other important stakeholders in diverse sectors (Tan and Taeihagh, 2020). Each actor in the Penta Helix plays one of the following roles: 1) Academics serve as concept developers who standardize product certification, business procedures, and human resource capabilities. Academics are also connected to knowledge sources that provide the most recent and pertinent concepts, and theories, 2) The business world facilitates. Business

is an entity that carries out business processes in maintaining sustainable growth while also creating added value; 3) The community acts as an accelerator, acting as a liaison between stakeholders, which are people who share the same interests as and are pertinent to the developing business; 4) The government serves as both a regulator and a controller, with regulations and responsibilities in developing business; and 5) Media serves as an accelerator (Ahmed et al., 2023).

The Penta Helix model is a neat and continuous collaboration concept from each task force within the framework of the success of a program or policy that is based on real contributions and active involvement from elements of (1) government (public sector); (2) private entities (private sector); (3) academics (academic sector); (4) non-governmental organizations (NGOs); and (5) the involvement of civil society (the civil society) (Carayannis and Campbell, 2010). The Penta Helix model is quite reliable when used as an analytical knife to study policies to combat plastic waste in the seas of Indonesia and China. The reliability of using the Penta Helix model in fighting plastic waste is based on the interpretation that environmental issues and problems are dynamic, have high complexity, and often involve many countries, so the methods or approaches used to solve them must be flexible. This means that the systems and steps taken must be adapted to the dynamics of science and technology development, where one of the issues in the development of science is the Penta Helix model.

This model proves particularly effective as an analytical tool for addressing the pressing issue of plastic waste in the seas of Indonesia and China (Dinansyah et al., 2024; Wungubelen et al., 2024). Its strength lies in its adaptability to the dynamic and complex nature of environmental challenges, which often span multiple countries and require collaborative solutions. The Penta Helix model recognizes that tackling plastic waste necessitates a flexible approach, one that evolves in response to advancements in science and technology. By integrating these diverse perspectives and resources, the model fosters a comprehensive strategy that can effectively address the multifaceted challenges of plastic pollution, making it a vital framework for sustainable environmental governance.

The issue of plastic waste is part of the complexity of environmental problems faced by every country. This study aims to show that the responsibility for overcoming the problem of plastic waste in the oceans is not only the responsibility of the government and it is not enough to be approached only with a command-and-control model approach, but also (simultaneously) collaboration of all stakeholders and optimizing the use of appropriate instruments or approaches. Still, it must be interpreted as an integrative effort to complement the strategy that has been implemented through the policies that have been implemented so far. In consonance, this study will outline the contribution of each Penta Helix element that has been implemented and policy breakthroughs (in the future) from each piece that can be taken related to the policy of fighting plastic waste in the seas of Indonesia and China, as well as outlining the obstacles faced by each element as a component of the Penta Helix model.

The Penta Helix concept, which involves cooperation between the government, academia, private sector, community, and media, has been the focus of novelty articles and efforts that have brought attention to a number of important methods and projects for tackling plastic debris in the seas of China and Indonesia. Important Findings and

Advancements The joint initiatives of Indonesia.National Plastic Action Partnership (NPAP): Indonesia has embraced the NPAP concept with the goal of eradicating plastic pollution by 2040 and reducing marine plastic leakage by 70% by 2025. By emphasizing reduction, reuse, and alternative distribution methods to gradually phase out single-use plastics, this strategy supports a circular economy. Government Policies: To address plastic pollution, the Indonesian government has put in place a number of strong policies, including the National Waste Management Policy and Strategy (Presidential Decree No. 97/2017) and the Plan of Action on Marine Plastic Debris 2018–2025 (Presidential Decree No. 83/2018). China's Initiatives: Although China's use of the Penta Helix model is less specific, the country has taken steps to reduce plastic waste through international partnerships and national policies that enhance waste management capabilities and encourage recycling. Collaborative Models: Multisectoral collaboration is encouraged by the Penta Helix model.

The Penta Helix idea, which entails collaboration among the government, university, business sector, community, and media, has been a central focus point in literature that addresses novel approaches and activities targeted at eliminating plastic waste in the seas of China and Indonesia. This collaborative structure has been acknowledged for its capacity to bring together a wide range of stakeholders, each contributing distinct capabilities and viewpoints. For example, research has revealed successful case studies in which government policies have been successfully supplemented by academic research, resulting in decision-making based on evidence that tackles particular environmental issues (Carayannis and Campbell, 2010).

Furthermore, the literature has examined several programs that demonstrate the practical implementation of the Penta Helix concept. These encompass community-driven clean-up initiatives that actively involve local communities, therefore cultivating a feeling of ownership and accountability towards the preservation of maritime environments. The private sector plays a pivotal role, as evidenced by several studies that outline how companies have embraced sustainable practices and collaborated with non-governmental organizations (NGOs) to create groundbreaking waste management solutions. Furthermore, scholarly contributions have offered significant perspectives on the socio-economic consequences of plastic pollution, which have shaped policy frameworks and increased public consciousness via media campaigns.

Numerous studies have demonstrated that the Penta Helix paradigm is especially successful in areas where socio-economic difficulties and cultural influences exacerbate environmental problems. The flexibility to adapt enables the use of customized strategies that take into account the specific circumstances of the locality, therefore facilitating the implementation of sustainable solutions. In conclusion, the increasing amount of scholarly work emphasizes the significance of the Penta Helix concept as a revolutionary method to address plastic waste. It implies that its cooperative character is crucial for developing efficient and enduring tactics in the battle against marine pollution in China and Indonesia.

2. Research methods

The research design employed a literature review method which gathered information from a variety of sources, including reputable international journals that are searched using three databases (science direct, scopus and web of science), rules, reports from the public and private sectors, and textbooks or handbooks about research problems and objectives, with a literature review duration of the last 10 years. The approach used to analyze data with maching patterns (Susilo et al., 2023). By employing this method, it is hoped to illustrate several ideas relevant to the issues being addressed or investigated and serve as a foundation for the justification of research findings . Researchers investigated the Penta Helix concept to lessen marine plastic waste in China and Indonesia. The inclusion criteria for this study were the results of research from various sources addressing the Penta Helix model as a comprehensive attempt to minimize marine plastic waste in Indonesia and China (Ifanov et al., 2023).

3. Results and discussion

Plastic product manufacturing, usage, disposal, and recycling have all been impacted by the Covid-19 pandemic (Yuan et al., 2021). During the pandemic, many individuals use personal protective equipment (PPE). Some disposable PPE, including face masks, gloves, personal protective equipment, eye protection, and respirators, are composed of plastic. According to information from June 2020, more than 50 nations globally required people to hide their faces or wear masks while the (Patricio et al., 2020). European Centre for Disease Prevention and Control (2021) recommended using a face mask to prevent the virus from spreading at the start of 2021. Since the COVID-19 pandemic, it is predicted that 1.6 million tons of plastic garbage will be produced every day worldwide (Benson et al., 2021). This indicates that each person accumulates 75 kilograms annually. According to estimates by Prata et al. (2020). 129 billion face masks and 65 billion gloves are used globally each month. Every day, 3.4 billion disposable face masks or shields are discovered in landfills worldwide (Benson et al., 2021). This is as visualized in **Table 1** below:

Table 1. Estimated amount of plastic waste per day globally per country to be managed (Benson et al., 2021).

Rank	Contry	Population	Urban Population	Facemask acceptance rate by population (%)	Average facemask per capita per day	Estimated daily facemask discerded	Total estimated plastic waste (Tonnes)
1	China	1,439,323,776	61	80	1	702,390,002	107,949,283,20
5	Indonesia	273,523,615	56	80	1	122,538,579	20,514,271,10

* Source: Benson et al., 2021.

The proportion of all plastic garbage produced since the COVID-19 pandemic breakout is shown in **Table 1** as a percentage. According to estimates, China required 1.6 million goggles, 76 million medical gloves, and 89 million medical masks. As the epidemic peaks, China produces 240 tons of medical waste daily, six times as much as Wuhan typically produces before pandemics like COVID-19 (Singh et al., 2020).

Nevertheless, the quantity is continually rising. According to the Chinese State Council Information Office, 468.9 tons of medical waste were collected throughout the epidemic. In addition, in 2020, the oceans received more than 1.56 billion face masks. This suggests that more than 4680 to 6240 metric tons of marine plastic pollution are carried by COVID-19 (Igalavithana et al., 2022). Pollutants made by plastic have a variety of detrimental effects. The negative impacts of plastic additives are quickly harming China's ecosystem. Phthalic acid esters are additives that are often utilized in a variety of plastic goods, including construction materials, medical equipment, food packaging plastics, and plastics for other agricultural uses in China's urban and agricultural soils, phthalic acid esters have been found at alarmingly high amounts (He et al., 2015).

The State Oceanic Administration (SOA) of China estimates that 81% of China's coastline regions are severely contaminated by plastic garbage. One of the primary factors lowering China's potential for tourism and waterfront real estate is plastic waste. Large-scale floating plastic also threatens the commercial sector that uses coastal waterways, damages nearby ships, and results in significant yearly financial losses. According to the currently available information, it is expected that China has discharged 39 tons of primary microplastics into the environment (Wang et al., 2019). The management of plastic trash in China and Indonesia is an example of using the Penta Helix in this field. The role of the public, private, academic, non-governmental organizations (NGOs), and civil society in actively contributing to plastic waste management is seen from the Penta Helix model of managing plastic waste (Carayannis and Campbell, 2010). The following describes how stakeholders participate actively in Penta Helix waste management and its methods.

3.1. Public sector

China is the highest plastic waste-producing country, so it acknowledges its need for a plastic waste management policy. China aims to implement policies to address the plastic problem (Sun et al., 2022). The Chinese Government has made several policies over the last decade to overcome the plastic waste crisis. Like other developed countries in the United States, United Kingdom and Australia), China has made relevant policies and banned plastic bags and other single-use products (Sun et al., 2022). In addition, some well-known franchises (e.g., Starbucks) have banned plastic cups and are using reusable containers to protect the health and safety of their customers (Coelho et al., 2020). The strategy of banning industrial waste has steadily been managed since the adoption of stricter environmental rules in 2017. Industrial waste has been subject to increasing levels of inspection since the implementation of the Plan for Banning the Import of Wastes and Promoting the Reforming of the Solid Wastes Import Management System (GBF [2017] No. 70). (International Pollutants and Shenzehn Zero Waste/Elimination Network (IPEN), 2022).

Since the enactment of more stringent environmental regulations in 2017, the policy of the prohibition on industrial waste has been gradually controlled. Industrial garbage has steadily been increasingly controlled with the implementation of the Plan for Banning the Import of Wastes and Promoting the Reforming of the Solid Wastes Import Management System (GBF [2017] No. 70). Small manufacturers and

companies that do not follow government regulations have been forced to close one after another due to significant pollution and anomalous performance of pollution control equipment. Since that time, China no longer imports a sizable amount of waste plastic. Though China no longer imports plastic waste, the market need for recycled plastic particles made from plastic waste is still growing (Turiel et al., 2017).

In 2018, the Government of China banned all imports of non-industrial plastic waste. Then, the Government called for the phasing out of non-degradable plastics in the country and improving production, consumption, recycling, and disposal mechanisms in 2020. The methods of assessing future landfills of plastic waste are essential for state policies to be implemented effectively (Sun et al., 2022). In China, 81.842 million tons of plastic products were produced in 2019. In contrast, China consumes over 70 million tons of plastic products with 70% of its plastic production is made from the top five synthetic resins. About 60% of them are polyethylene (PE) and polypropylene (PP), which are mostly used to create single-use plastic goods like plastic packaging and film, according to the China Plastics Industry Yearbook. There were also 8.84 million tons of PET bottle chips manufactured, which are mostly used to build plastic bottles (Liu and Liu, 2023). This is as visualized in **Table 2** below:

Table 2. China's production of five main plastic rensins from 2015 to 2019 (Million Tonnes).

Year	2015	2016	2017	2018	2019
Total resins	77.182	80.182	82.136	85.58	95.74
PE	13.855	14.355	13.363	14.02	17.449
PP	16.864	18.106	19.035	20.419	23.485
PVC	16.190	16.899	17.745	18.739	20.107
PS	3.053	1.958	2.025	1.757	2.983
ABS	3.089	3.098	3.244	3.258	3.93

Source: China Plastic Industry Yearbooks, which include classified data and synthetic resin information from 2016 to 2020; the National Bureau of Statistics (NBS), which provides information on the overall output of plastic products (Liu and Liu, 2023).

There is an amazing amount of plastic waste produced by the widespread use of plastic. Of the 63 million tonnes of plastic garbage produced in China in 2019, about one-third was recycled, burnt, or buried, and the remaining 7% was released into the environment. 18.9 million tons of recycled plastic waste were generated in 2019, an increase of 600,000 tons from the previous year. The figure is twice as high in the EU while being seven times higher in the US. As visualized in **Figure 1** below:

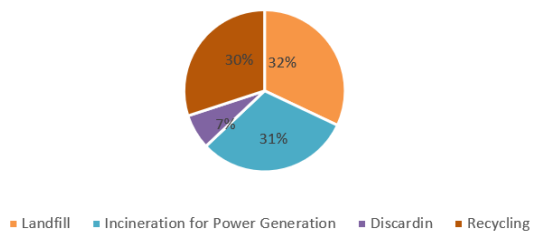

Figure 1. The volume and percentage of plastic garbage that was processed in China in 2019.

Source: International Pollutants and Shenzehn Zero Waste/Elimination Network (IPEN) (2022).

In their article, Sun et al. (2022) provide a "win-win" solution for managing waste in China, wherein plastic waste management policies must pay attention to environmental sustainability and earn economic income. According to three alternative scenarios (Business as usual, Current Policy Scenario, and Target Policy Scenario), Sun et al. forecast China's plastic waste creation and handling costs from 2020 to 2035. The effects of these initiatives are separated into three areas for China to employ. To determine the confidence interval of the evaluation, scenario analysis and Monte Carlo simulation were also performed. The findings indicate that by 2035, plastic waste emissions will be 34.82 million tons under BAU, 13.49 million tons under CPS, and 2.63 million tons under TPS, and that the region's contribution to plastic waste emissions will significantly alter. For example, the Western Region: 29.1% to 45.7%, the Central Region: 25.2% to 30.9%, and the Eastern Region: 45.7% to 9.7%.

Characterization of marine debris has also been conducted to support decision-making. China is the largest coastal country in the world. In the eastern part of China, Xiamen, the average densities of floating, stranded, benthic, and floating microplastic debris (0.5–5 mm) were 3963 ± 2027 items km^2, 0.13 ± 0.08 items m^2, 20,274 ± 15,873 items km^2, and 36,455 ± 33,935 items km^2, respectively (Chen et al., 2019). In this area, low-value waste is recycled into grocery bags, rope, and foam. This type of waste is most prevalent in East China waters. The waste comes from domestic activities as well as local fisheries. There are also benthic waste types where benthic waste characterizes both economic disparities and urban and rural waste management strategies (Chen et al., 2019). Waste sources are poorly managed, and there are still neglected waste management systems.

Research on the marine waste management policy process shows that 11 coastal provinces of China are in decline. Developed provinces such as Jiangsu, Zhejiang, Shanghai, and Guangdong have low efficiency of political attention (Yang, 2023).

3.2. Private sector

Industrial, medical, agricultural, and home sources of plastic waste may all be categorized (Ma et al., 2023). Most of the plastic trash produced by industrial sources takes the form of plant waste or residue. Industrial plastic trash has the qualities of high grade purity and convenience of collection; the majority of industrial plastic waste is transported to particular plastic recyclers or utilized again directly in industries (Kibria et al., 2023).

A qualified entity must recycle plastic garbage from medical facilities as it may contain poisonous, radioactive, or other harmful materials and be a source of infection. When we talk about plastic trash from agricultural sources, we mostly mean the waste from mulch films, greenhouse films, pipes, packages, and other items that are challenging to collect and recycle after use. This fraction of the plastic trash has typically been disregarded in statistics on the process of gathering, moving, and handling municipal solid waste (MSW). Global Pollutants and the Shenzhen Zero Trash/Elimination System (International Pollutants and Shenzehn Zero Waste/Elimination Network (IPEN), 2022). China's attempts to limit pollutants from plastic trash produced on land have become a warning flag.

The main means of support for residential waste plastic recycling in China is provided by two systems, one for recovering renewable resources and the other for collecting and transporting municipal waste (**Figure 2**). People collect plastic garbage by going door-to-door and selling it, which has significantly contributed to recovering renewable resources. Prior to being acquired, recovered garbage is first classified, then further processed through downstream recovery, and then supplied to recyclers for processing and use. This is as visualized in **Figures 2** and **3** below:

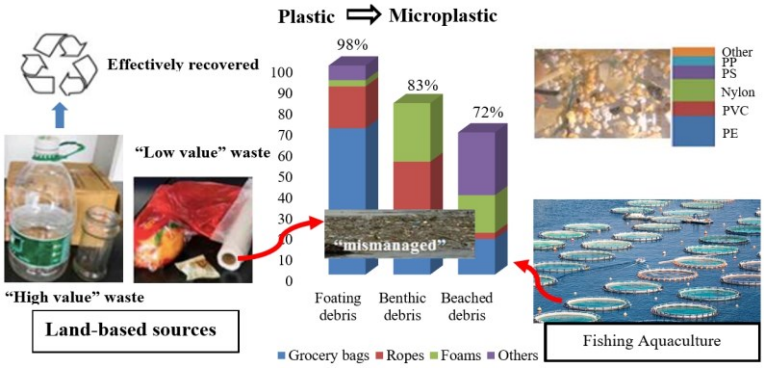

Figure 2. Marine waste that is not managed well in tourist city areas in China.
Source: Chen et al. (2019).

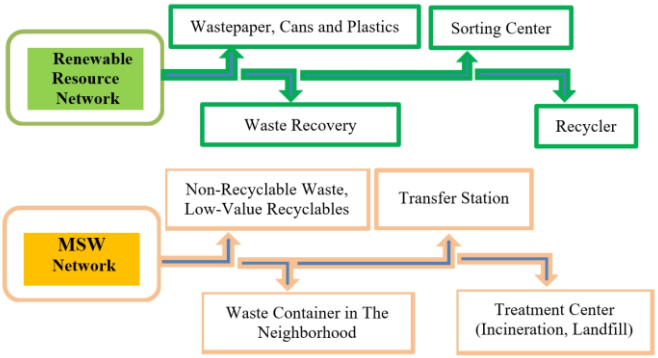

Figure 3. The recycling system.
Source: International pollutants and shenzehn zero waste/elimination network ((IPEN), 2022).

The Chinese renewable resources sector has grown from a small, family-run business to a sizable enterprise group. It is evolving toward a model in which significant businesses establish upstream recovery outlets. The Department of Urban Management oversees the waste collection and transportation system. The urban sanitation system collects and transports the waste centrally to the transfer facility. After a second round of sorting, the transfer station sends the valuable recyclables, including plastic waste, to the processing facility for MSW while keeping the rest of the material. Currently, the two main waste treatment techniques are sanitary landfills and incineration.

Sea cleanliness is also aided by the private sector's involvement in the management of plastic garbage in the ocean. Waste can be managed by the private sector to provide economic benefit. Research by Zhao et al. (2023) indicates that managing plastic garbage in the ocean has potential economic benefits. The feasibility of cooperation in marine plastic waste management is based on the cooperative

network game model, which takes into account the following factors: 1) the amount of waste and the level of governance technology; 2) the size of the cooperation alliance; 3) the form of cooperation; and 4) technological innovation. The Penta Helix Model's Success explores the model's effectiveness in addressing plastic waste in China's oceans. The media, academia, business, civil society, and government participation are evaluated. Difficulties with Implementation: Although the Penta Helix idea is intriguing, putting it into practice is challenging. We'll talk about obstacles like interest disparities, uneven party involvement, and cross-sector collaboration. The government's support for sustainable plastic waste management laws and regulations is the main topic of discussion (Spadaro et al., 2023). Included are funds for waste management infrastructure, industry oversight, and incentives for technical innovation. Innovation and Technology demonstrates how business and academia collaborate to decrease the use of single-use plastics, improve recycling, or swap them out with environmentally benign alternatives (Bradu et al., 2023). It was also explored how civil society can become involved in fundraising, awareness initiatives, and beach clean-ups. Public education regarding the risks and mitigation of plastic garbage is one area of concern (Liu and Liu, 2023). The discussion will also evaluate the significance of regional collaboration in reducing plastic trash, including cooperative marine resource management and cross-border policy harmonisation, given the size and division of the China Sea among many nations. By examining these themes, we can clarify how the Penta Helix model might be applied to address the issue of plastic trash in the China Sea and identify areas that require further development and attention.

3.3. Academic sector

Academics in China provide recommendations for sophisticated recycling methods. The role of universities in research on the topic of plastic waste management is urgently needed. Many universities in China provide policy briefs to the government to provide policy recommendations. With the active role of academics, plastic waste management is increasingly sophisticated (Maitlo et al., 2022).

Campus academics also provide community service on cleanliness and how to sort plastic waste. Plastic waste can improve the community's economy if it is appropriately processed. The use of recycled plastic waste provides more significant benefits. However, academics could be more optimal in providing socialization to the community to call for reducing the use of single-use plastics (Song et al., 2023).

3.4. Non governmental organization

Marine litter is the area of expertise for the NGO Rendu Ocean Centre in mainland China (Krushelnytska, 2018). Liu Yong Long, the creator of Rendu Ocean Centre, carries out tasks including collecting marine trash, monitoring and research, environmental education, and working with NGOs. Rendu Ocean Centre has much experience working with Chinese and international NGOs and is one of the most active sector-wide collaboration and development boosters.

China will inevitably rank among the top producers of plastic goods, given its position as the largest manufacturer and supplier in the world. With a vast population, China is also one of the countries that consumes most plastic. From the Bohai marine,

the Yellow Sea, to the East and South China Seas, China has a sizable marine area, and several rivers flow into these seas. Typically, there is a significant concentration of people and economic activity in watersheds and coastal areas. Several of the populous nations in East Asia and the Pacific have marine boundaries at the same time. As a result, pressure and difficulties are placed on the marine environment and its ecology by the plastic garbage produced by human activities close to the sea (Fürst and Feng, 2022).

3.5. The civil society

One of the biggest producers and importers of trash worldwide is China. Marine debris (MD) is mainly produced by industrial and domestic garbage, then disposed of. According to (Kang et al., 2022) there are three different distributions of marine debris: beach-stranded debris (BMD), floating debris on the water's surface (FMD), and submerged debris in sediments (SMD). Intense aquaculture, fishing, and other household activities related to fisheries are some of the major contributors to marine waste. Marine debris is integrated into and collected by marine species through the food chain, ultimately posing dangers to the biological environment, economic advantages, and human health. Marine debris demonstrates multiple forms of leaching, degradation, and fragmentation (Kang et al., 2022).

One of the biggest producers and importers of trash worldwide is China. Marine debris (MD) is mainly produced by industrial and domestic garbage, then disposed of. According to Kibria et al. (2023), there are three different distributions of marine debris: beach-stranded debris (BMD), floating debris on the water's surface (FMD), and submerged debris in sediments (SMD). Intense aquaculture, fishing, and other household activities related to fisheries are some of the major contributors to marine waste. Marine debris is integrated into and collected by marine species through the food chain, ultimately posing dangers to the biological environment, economic advantages, and human health. Marine debris demonstrates multiple forms of leaching, degradation, and fragmentation (Liu and Liu, 2023). This is as visualized in **Figure 4** below:

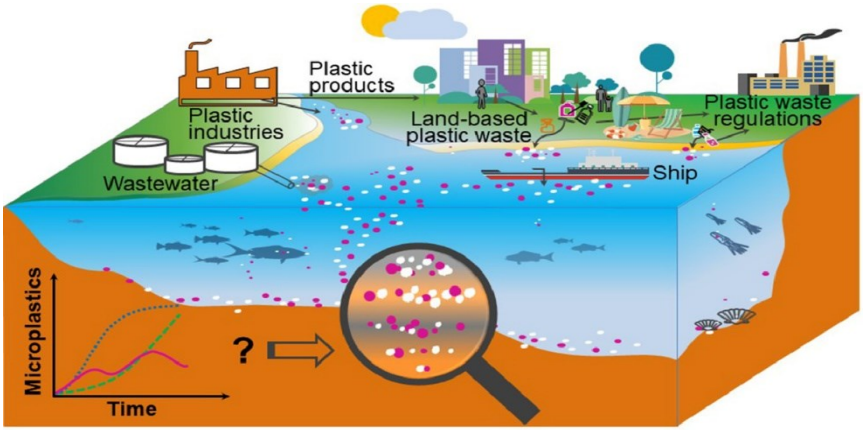

Figure 4. Marine waste integration.

Source: Liu and Liu (2023).

In China, community involvement in plastic recycling serves two functions. To start, identifying plastic garbage will aid in improving its quality and rate of recovery.

Second, promote the use of products made from recycled plastic to expand the market for recycled plastic. Recycling of plastic garbage is becoming increasingly sophisticated, and PET bottle recycling machinery is becoming more advanced and is now readily available in many cities. Shortly, scavengers and independent contractors will continue to control the extraction and classification of valuable plastic waste. First, there are so many distinct varieties of plastic materials that it can be challenging for most customers to distinguish between them. In the middle and late 20th century, plastic items began to use Resin Identification Codes (RICs). In China, community involvement in plastic recycling serves two functions. To start, identifying plastic garbage will aid in improving its quality and rate of recovery. Second, promote the use of products made from recycled plastic to expand the market for recycled plastic. Recycling of plastic garbage is becoming increasingly sophisticated, and PET bottle recycling machinery is becoming more advanced and is now readily available in many cities. Shortly, scavengers and independent contractors will continue to dominate the recovery and sorting of high-value plastic debris. There are so many distinct varieties of plastic materials that it can be challenging for most customers to distinguish between them. In the middle and late 20th century, plastic items began to use Resin Identification Codes (RICs).

Seventy-eight percent of the public stated they would use products created from recycled materials when reusing waste, according to study findings. Additionally, it expands the industrial chain for resource reuse markets. However, many people believe that recycled plastic comes from many tiny, poorly regulated businesses that seriously pollute the environment; for recycled plastic products to be trusted and understood by the general public, government education and advice must be improved. Encouraging people to understand the importance of sustainable development and the need for plastic recycling in order to make the transition from a linear to a circular economy.

4. Penta helix of plastic waste management in Indonesia

4.1. Public sector

The penta helix model for Indonesian maritime waterways integrates the following sectors: media, government, industry, university, and civil society. Given that Indonesian waters are among those most impacted by the global plastic waste problem both geographically and ecologically, it will take into account the ecological effects of plastic waste on marine biodiversity and ecosystem health as well as the urgency of taking coordinated action to lessen its detrimental effects (Kamaruddin et al., 2022). Additionally, it will look at how cooperation between these sectors can enhance efforts to control and lessen plastic waste in Indonesian waters (Veiga et al., 2023); the role of the government in developing policies for the sustainable management of plastic waste, overseeing industries that use plastic, and providing funding for waste management infrastructure (Zhang et al., 2024); The Penta Helix model encourages technological and commercial innovation to provide environmentally friendly solutions like plastic substitutes, more efficient recycling, and biodegradable goods (Charina et al., 2022). It was considered how civil society

may help manage and clean up plastic debris on Indonesian beaches and waterways while also educating people about the dangers of plastic waste (Markley and Olivelli, 2022). The conversation will also cover the advantages of sharing expertise and experience in putting into practice workable solutions, as well as the significance of regional collaboration with other nations and the global community in tackling plastic trash.

This discussion should highlight the obstacles that need to be overcome in order to implement the Penta Helix model in various Indonesian provinces, districts, and cities, including West Java, Java, and Bali. It should also highlight how the model can mobilise different parties to reduce and eliminate plastic waste in Indonesian waters.

The government has a strategic role in making policies to reduce plastic waste. Government policy is one of controlling the amount of waste circulating in society. The Ministry of Environment and Forestry of the Republic of Indonesia has a role in reducing and circulating plastic waste. This role is useful in preventing the development of the "blue economy" (Zhao et al., 2023). The global problem of marine plastic pollution has emerged, along with the loss of biodiversity and the acceleration of climate change. Global involvement in marine plastic waste regulation is necessary due to important environmental factors, ocean water diversity, administrative boundary uncertainty, and administrative complexity. To address ocean plastic trash, all stakeholders must take proactive measures. At now, approximately 60 nations have established goals for governance and implemented pertinent laws. (United Nations Environment Programme, 2018). The G20 Osaka Summit in 2019 adopted the "Blue Ocean Vision" initiative to achieve the goal of "zero emissions" of marine plastic waste by 2050. The United Nations Environment Programme (UNEP) has launched the "Clean Sea" campaign to find solutions to reduce marine waste. and 63 countries participated (Abate et al., 2019). The Ellen MacArthur Foundation (EMF), in partnership with UNEP, has established the "New Plastics Economy" global commitment to promote the development of a circular economy in the plastics sector, with 400 signatories (Forum, 2016). The "Nature Plastic Nett 2030" programme, which aims to eliminate plastic pollution by strengthening the global governance framework and quickening the shift to a sustainable environment, has also been proposed by the Worldwide Fund for Nature (WWF). the circular economy (WWF, 2019). In Indonesia, there is also a campaign to "zero marine litter" by 2025 (Peter Manyara, 2022).The campaign involves active community participation.

In Indonesia, the final processing of waste in general in Indonesia uses a land disposal system (removal of waste into the ground). Waste disposal into the ground, is known as landfilling. Sanitary landfill is a landfilling method whose application considers aspects of environmental sanitation (Lucentezza et al., 2021). Therefore, some of the Indonesian government's policies in reducing plastic waste are as follows. This is as visualized in **Figure 5** below:

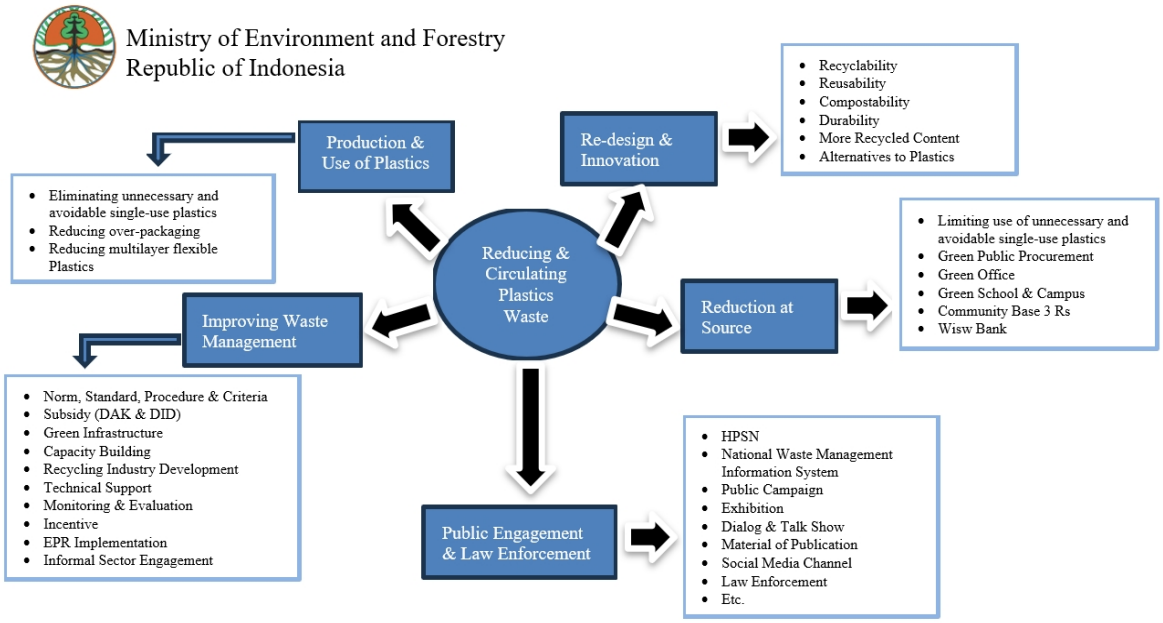

Figure 5. Policy in reducing and circulating plastics waste in Indonesia.
Source: Lucentezza et al., 2021.

4.2. Private sector

The management of trash is of importance to many parties. Municipal authorities collect most garbage after consumers have disposed it, and it is then sent to landfills (landfills) via 3R centers, waste banks, the unofficial economy, and recyclers. There are additional collection methods, such as unofficial collections and programs run by the FMCG industry. The private sector's job is to identify business opportunities in waste management, such as private garbage collection businesses, businesses that only sell recycled materials, and others (Keban, 2008).

Businesses that offer recycled products in Bali can get materials like PET bottles and aluminum from garbage collectors and vending machines. A plastic crushing facility owned by Ecojos processes 540 tons of PET per month. PET bottles are collected via drop boxes and waste collectors at stores. Additionally, BaliPET operates a plastic-crushing facility with a monthly capacity of 500 tons of PET. The MoEF recently supported the formation of Indonesian Waste Banks (ASOBSI), an organization of waste banks in Indonesia. Every province in Indonesia is expected to have ASOBSI members. Members of the Indonesian Scavengers Association (IPI), a group of waste collectors, include recyclers, poolers, and scavengers. IPI reports that at the moment, Indonesia has more than 2 million people who work as scavengers (Ardiyatna and Anityasari, 2021).

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4.3. Academic sector

Academics play a role in providing recommendations for waste management. Several universities actively fight plastic waste through community service and policy recommendations. Academics with community service tasks can campaign for equipment that can be used often. The use of single-use utensils, especially using plastic, is not recommended because the volume of plastic has increased rapidly. Community service, especially the community on the banks of the river, to strengthen the community in saving the river ecosystem from the threat of plastic (Maulidya, 2020). This is as visualized in **Table 3** below:

Table 3. The role of academics.

No	Actor	Role	Synergy
1.	UINSA	Establishment of a waste ban, utilization of leachate water, making compost	Good
2.	SMPN 6 Kota Metro	There is a special team for waste bank management	Good
3.	Lecturer of UINSA	Collaborative and act as a consultant with DLH in waste handling	Good

Source: Maulidya (2020).

4.4. NGOs

Non-governmental organizations are involved in various public action areas, such as environmental protection, human rights, and development. A few NGOs with an emphasis on controlling plastic waste are Trash Hero Jakarta, Sea Soldier Jakarta, Divers Clean Action, Osoji Jakarta, and KEHATI Foundation. Rash Hero is managed, supported, and led by Trash Hero World, a worldwide volunteer movement founded in 2013 and centered in Thailand. Over 5269 places are covered by its clean-up program, which has 177,023 volunteers worldwide. Trash Hero is now accessible in

the following 12 nations: Australia, Indonesia, Malaysia, Thailand, Laos, Myanmar, the Czech Republic, Romania, Switzerland, Serbia, Laos, Myanmar, and the United States. The bottle bag program and partnership with Trash Hero cover the company's operations expenses. The following shows how NGOs fit into the picture (Chotimah et al., 2022). This is as visualized in **Figure 6** below:

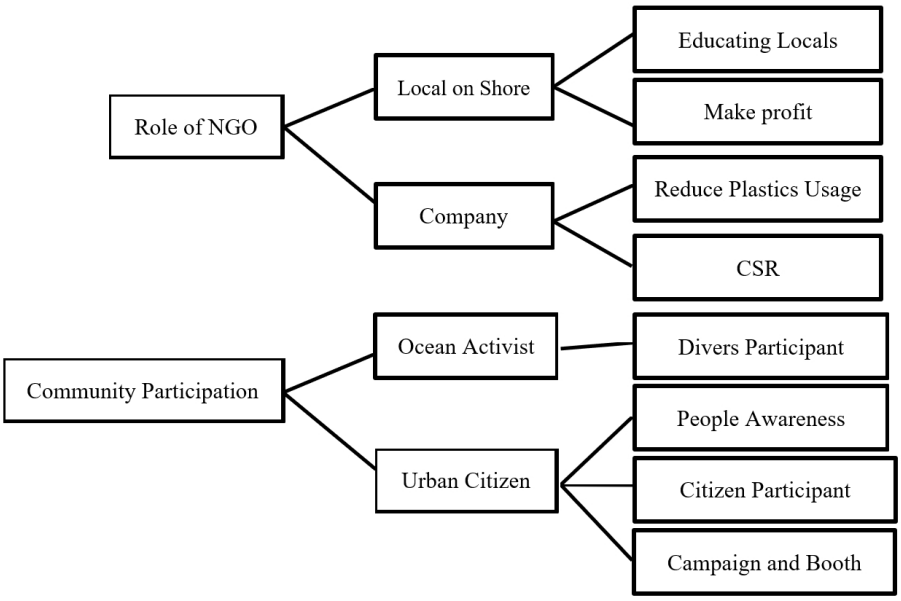

Figure 6. Roles of NGOs in plastic waste managements.
Source: Chotimah et al. (2022).

Locals are already motivated since they directly experience the effects of ocean pollution and NGOs can help them become more knowledgeable while also improving their quality of life. Life. a program run by Trash Hero and KEHATI teaches residents how to recycle their plastic garbage and benefit from it. This approach can increase residents' motivation while improving their quality of life due to the financial benefits. Additionally, maintaining their shoreline and ocean would attract more visitors and boost people's revenue. The most formidable challenge in reducing plastic is when producers are still producing. NGOs play a role in finding solutions between producers and consumers to reduce the use of plastic. In 2017, the NGO collaborated with fast-food restaurants to replace plastic straws with stainless straws (Hermawan et al., 2021). The movement to change the use of reusable straws is acceptable to the community, including using non-plastic shopping bags. The role of NGOs is vast in socializing the movement without plastic.

4.5. Civil society engagement

Community participation in waste management is needed. Many plastic waste management programs involve the community. The strategy for getting the public to support government initiatives to improve cleanliness is to get them used to a certain standard of conduct. Community participation starts from plastic waste disposal, processing, and sorting to recycling. The community can help by disposing of waste in its place and then participating in sorting plastic waste. People can also recycle plastic waste (Putra and Yuriandala, 2010). Processing plastic trash is one way to

promote environmental cleanliness and reduce plastic waste production. By using recovered plastic garbage, creative objects made from plastic waste may also be produced (Yuliadi et al., 2017). This is as visualized in **Table 4** below:

Table 4. Literature review model penta helix results.

No	Model Penta Helix	China	Indonesia
1.	Public Sector	The government is urging the gradual phase out of non-biodegradable plastic by 2020 following the publication of the implementation Plan for Banning the import of wastes and Promoting the Reforming of the Solid Wastes Import Management System (GBF, 2017), No. 70, also known as the Ban on wastes policy. Industrial waste will be regulated in stages beginning in 2018, when all imports of non industrial plastic waste will be prohibited.	Minister of Transportation Regulation Number 29 of 2014. About Prevention of Maritime Enivironmental Pollution is one of the Indonesian government's strategies to reduce plastics waste. Roadmap for Waste Reduction by Producers: Minister of Environmental and Forestry Regulation No. 75 of 2019. Republic of Indonesia Government Regulation Number 27 of 2020 regarding Specific Waste Management was also issued by the government to control waste from producers who create, import, distribute, and/or sell products with packaging that is either impractical or difficult to decompose naturally.
2.	Privat Sector	Domestic waste plastic recycling is based on two system : a system for recovering renewable resources and a system for collecting and moving municipal garbage.	The private sector carries out waste collection, companies with the sale of recycling only as an economic opportunity in waste management.
3.	Academic Sector	Universities provide policy briefs to the government and campus academics also provide community service regarding cleanliness and how to sort plastic waste, although it seems that the role of academics is not optimal in providing community outreach to call for savings in the use of single- use plastics.	Several Universities are active in fighting platic waste through community service duties can campaign for the use of equipment that can be used repeatedly. The use of single-use equipment, especially using plastics, is not recommended because. The volume of plastic has increased rapidly.
4.	The Civil Society	According to the Vanke Pondation's 2020 Urban Population trust And Awarennes of MSW Management Index Report, citizens trust in trust management, awareness of waste management, and MSW categorization accuracy have all grown over the previous three years. However, public trash management still must be improved given the stark variations between cities.	Familiarize people with a level of behavior that is accordance with cleanliness. Community participation starts from platic waste disposal, plastic waste processing, sorting, to recycling. The public can help by throwing rubbish in the right place, and then participating in sorting plastic waste. People can also recyle platic waste.
5.	Non Governmental Organization (NGO)	Rendu Ocean Center, Founded by Liu Yong Long, is one of the most prominent proponents of sectoral cooperation and growth and mainland China. It focuses on garbage and work closely with both Chinese and foreign NGO.	Non governmental organizations are involved in a wide range of areas of public action, including development, human right, humanitarian aid, the environtment, and many more, Trush Hero Jakarta, Divers Clean Action, Sea Soldier Jakarta, Osoji Jakarta, and KEHATI Foundation are a few NGOs focused on controlling plastic garbage. Trush Hero World, which was established in Thailand in 2013, leads sponsors, and coordinates the worldwide volunteers movement known as rash Hero, it has 177,023 volunteers globally, and its cleanup initiatives have a global reach of 5,269 locations. Trash Hero is available in 12 different nation worldwide: Australia, Indonesia, Thailand, Malaysia, Myanmar, Laos, Singapore, the Czech Republic, Romania, and Serbia

5. Conclusion

The management of plastic waste in Indonesia is quite good. The Penta Helix model of cooperation in managing plastic waste could have gone better. Sectoral ego still colors the implementation of government policies in plastic waste. The role of non-governmental organizations is good, where NGOs have made efforts to prevent the disposal of plastic into the sea. The remaining three elements: academia, business, and the role of the media, need special attention and be improved.

Meanwhile, the Penta Helix model stakeholder collaboration has been going well in China, assuming each element forming the Penta Helix model is utilized in a measurable and integrated manner. In that case, the target of reducing marine plastic waste will be realized more quickly, and in the long term, it will also be beneficial for sustainably maintaining marine ecosystems.

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