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Review of Waste Management in Indonesian Small Islands in the Last Five Years (2018-2023)

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Abstract: Indonesia is a maritime country composed of 16,771 islands consisting of large islands and small islands. One of the environmental problems that occur in small islands. Waste management is a shared focus because sources of water, soil and air pollution can

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come from waste. Waste management on small islands is very important because small islands have a much higher vulnerability than large islands.. This article aims to identify and analyze waste management in Indonesia's Small Islands and evaluate if its implementation has utilized the technology and concepts of the Industrial Revolution 4.0. Based on the findings of a review of 14 articles published from 2018-2023, with 15 islands as research objects, it was found that most of the small islands used as research objects had not managed their waste properly. The waste is eventually dumped into the sea. The unmanaged factor of this waste can be caused by the geographical conditions on the island which are bordered by the sea, the lack of waste management facilities, the limited land area on small islands and the low awareness and participation of the community in waste management. The rest, several islands have carried out the process of storage, processing, collection and destruction quite well. The waste is turned into handicrafts (bags and souvenirs), ecobricks, garden decorations and plant fertilizers for organic waste as well as the development of innovative waste into diesel fuel. Unfortunately, the intended application based on the Industrial Revolution 4.0 has not been reflected in waste management on these small islands. This is expected to be information and input for the government and managers as a model for other small islands in an effort to manage waste generation on the island's mainland and garbage contamination in the sea.

Keywords: *Garbage; industrial revolution 4.0; management; small Island*

Introduction

Indonesia is a maritime country formed by 16,671 islands which was reported to the UN through the UNGEGN (United Nation Group of Experts on Geographical Names) session in 2019, then there was an increase in the number of islands to 16,771 islands in 2020 which were listed on the National Gasetir. A total of 16,771 islands consist of large islands and small islands with a total area of Indonesia of ±7.81 million km^2 and around 62% of this area is seas and waters (Port Health Office, 2020; Indonesiabaik.id, 2018) .

In Indonesia there are five major islands, namely the islands of Sumatra, Java, Kalimantan, Sulawesi and Papua Island and there are many small islands scattered across these large islands. Sumatra Island has 3,665 islands, Sulawesi Island has 2,924 islands, Kalimantan Island has 932 islands, Java Island has 757 islands and Papua Island has 598 islands (Frida, 2022) and as many as 111 islands in Indonesia are designated as Outermost Small Islands which have been listed in the Presidential Decree (KEPPRES) 2017 concerning Designation of Outermost Small Islands.

According to Law Number 1 of 2014 the definition of a Small Island is an island that has an area of not more than or equal to two thousand square kilometers (2,000 km^2) with an Ecosystem in it. One of the environmental problems currently occurring on small islands and large islands is the problem of waste generation. Whether on a small or large island, the volume of waste generated is still one of the priority issues that must be resolved. Waste management is very important because sources of water, soil and air pollution can come from the waste.

Waste management on small islands is very important, because small islands have a much higher vulnerability than large islands. Several factors cause small islands to be very vulnerable including limited natural resources, vulnerability to climate change (such as rising sea levels, extreme weather, and changes in rainfall patterns), vulnerability to pollution (such as problems in waste and waste management) and economic dependence on certain sectors, where small islands often rely on one or two main economic sectors (Stojanović et al., 2019). Therefore, waste management on small islands must also be a priority in handling environmental problems, especially those caused by waste. Based on the Book of Procedures for Implementing a Waste Management System on a Small Island (Ministry of Public Works and Public Housing, 2016) waste management on a small island

by reducing can be done by limiting, recycling and reuse, while for waste handling can be done from the process of container, collection, transfer/processing and final processing.

But at this time, the Industrial Revolution 4.0 has penetrated into various fields (Abadi, 2021), including in waste management. Where, waste management based on the Industrial Revolution 4.0 helps increase process efficiency and utilizes advanced technology, including through optimizing resources to reduce negative impacts on the environment (Khan et al., 2019). Therefore, waste management that is carried out from the process of containerization, collection, transfer/processing and final processing needs to be carried out using advanced technology such as IoT sensors installed in trash cans that can monitor filling and collection automatically as well as optimizing waste collection routes (Huang et al., 2020). The use of technology such as AI, data analytics, and robotics is also needed in waste management to identify the type of waste, sort it automatically, and optimize the recycling process (Zaman et al., 2019). As a developing country, Indonesia needs to be one of the countries that encourages the necessity to initiate major changes in this technological era.

In fact, the results of observations made by the Ministry of Public Works and Public Housing (2016) regarding the condition of the main problems in waste management on small islands today are the limited land for waste processing, because the limited size of small islands makes it impossible to build a landfill (TPA). End), so that the waste from the small island must be taken to another nearby island that has a landfill for further processing. However, the obstacles in this transportation are the limited transportation of waste carriers and the high costs required to transport the waste. The low participation and awareness of the small island community in waste management is also a major problem in waste management. The application of 4.0-based technology is not visible in the waste handling process.

Identifying waste management in Indonesian Small Islands related to the application of technology and the concept of Industrial Revolution 4.0 needs to be done to understand the extent to which technology has been adopted and identify barriers and opportunities for its application, which is useful for governments and managers in developing appropriate policies.

A review of 14 articles published from 2018-2023, with 15 islands used as research objects, was conducted to answer several important questions related to the current condition of waste management in Indonesian Small Islands, then the extent to which technology and the concept of Industrial Revolution 4.0 have been applied in waste management in the region, and what policy recommendations and strategies can be implemented to improve waste management in Indonesian Small Islands. This identification will help in developing policy recommendations that are based on real data and evidence, so as to increase the implementation of technology in waste management more broadly and effectively.

Through proper identification, small islands can serve as pilot models for other regions facing similar challenges. This research can provide concrete and practical inputs for more sustainable and environmentally friendly waste management, supporting sustainable development goals. Thus, this research not only contributes to the academic literature but also has a significant practical impact for environmental management in small islands.

Research Method

The method used in this article is a literature review, in which the author reviews several articles available online with the keyword "Waste Management in Small Islands in Indonesia" so that several articles appear from the studies that have been carried out and

taken into account in this study. the last five years, in 2018 -2023, so that 14 articles with 15 islands were used as research objects, namely Pramuka Island, the Thousand Islands (Anna et al., 2023; Dyah et al., 2020; Nasution & Tjahjani, 2019), Kodingareng Lompo Island, Small Island Makassar City (Birawida et al., 2018), Kumo and Kakara Islands, North Halmahera Regency (Dobik, 2018), Lengkang Kecil Island, Batam City (Prajati & Widiantoro, 2019; Adicita et al., 2020), Untung Jawa Island, Thousand Islands (Darwati, 2019), Lengkang Island, Batam City (Adicita et al., 2020), Thousand Islands Administrative Region (Hartono, 2020), Small Islands on Aceh Island (February, 2020), Harapan Island, Thousand Islands (Dyah et al., 2020), Karimunjawa Islands, Jepara Regency (Prabawa et al., 2020), Balang Lompo Island, Pangkajene Islands District (Arya et al., 2021), Maringkik Island, East Lombok Regency (Mulyan & Hidayatullah, 2021), Kapoposang Island, South Sulawesi (Fachry, 2021), Tunda Island, Serang Regency (Cahyadi et al., 2021), Lengkang Island, Batam City (Adicita et al., 2022) and Lemukutan Island, Bengkayang Regency (Wahyudi et al., 2023) .

These articles were chosen because they explain the existing condition of waste management in small islands in Indonesia in the last five years and explain the factors of the problem of waste management in these small islands. The systematic review conducted in this paper is based on the following steps:

1. Identification of waste management carried out in small islands.
2. Identification of problem factors related to waste management in small islands.
3. Identification of the application of waste management on small islands based on the industrial revolution 4.0.

The Systematic literature review method involves a comprehensive and structured literature search using specific keywords, with the aim of identifying, assessing and synthesizing relevant evidence on a particular topic. The process includes the development of a clear search protocol, application of strict inclusion and exclusion criteria, and critical assessment of the quality of included studies.

This systematic literature review can thus produce robust and informed conclusions regarding waste management practices in Indonesia's small islands, providing a solid basis for policy recommendations and best practices in waste management in small island environments.

Results and Discussions

The conditions of waste management carried out on 15 small islands in Indonesia which were used as research objects obtained from 14 articles published in 2018-2023 are shown in the table below.

Table 1. Waste Management in Several Small Islands in Indonesia

No.	Authors, Year	Location	Area (ha)	Waste management
1.	Birawida et al., 2018	Kodingareng Lompo Island, Small Island in Makassar City	48	• The condition of garbage in the home area with lots of garbage scattered and piled up is 49.4%. • None of the respondents did household waste segregation. • Garbage is collected in trash bins and then 98.9% throws it into the sea.
2.	Dobik, 2018	Kumo Island , North Halmahera Regency	61.55	The absence of a temporary waste collection facility (TPS) causes people to throw garbage in their own yards and there are also people who throw it directly into the sea.
		Kakara Island , North Halmahera Regency	204.99	
3.	Prajati & Widiantoro, 2019	Small Lengkang Island , Batam City		• The majority of houses on this island do not have trash cans and do not carry out waste segregation. • Garbage generated in every house will be directly dumped into the sea. • There are no officers who collect garbage from house to house. • The condition of TPS size is very small. • The islanders will only move to dispose of the garbage that has accumulated when the smell of the garbage is very disturbing.
4.	Darwati, 2019	Lucky Island Java , Thousand Islands	103	• Sorting only by Scavengers and NGOs. • Containers are placed every 100–200 m along the main roads • Garbage collection is transferred directly to the transport ship or to the pool belongs to the residents if the transport ship has not arrived. • Processing with incinerator is no longer working. • Garbage final processing is transported by transport ships to Jakarta or stockpiled in ponds owned by residents and then burned.
5.	Nasution & Tjahjani, 2019	Pramuka Island , Thousand Islands	16	• Container: The community accommodated in containers that were provided independently and part of the assistance LMK and Government. The community rarely separates organic and inorganic waste (there are several

			places for distributing waste but the waste is still mixed). • Processing: Some residents make handicrafts from waste (bags and wallets) and some do composting. • Collection/Transfer: Before being transported and collected to the disposal site, the waste is collected by the garbage collector at the Waste Disposal Site (LPS) with a garbage cart. • Annihilation: Most people destroy waste by dumping it or burning it. 70-80% of waste does not end up in landfills but around residential areas and in the sea.
6.	Adicita et al., 2020	Island Lengkang, Batam City	• Lack of land causes a lack of waste management facilities. • No the existence of good facilities causes the sea to be targeted community as a waste disposal location (considered as a practical habit for residents).
7.	Hartono, 2020	Thousand Islands Administrative Region	Waste management efforts that are being carried out by the Tribe Thousand Islands Administrative District Environmental Service: • Destruction of Organic Waste through the L-Box incinerator with ionization combustion with a temperature of 100–200^{o} C. The waste that is successfully destroyed is 300–1,100 kg/day. Currently, there are 10 operating L-Box units spread across 11 inhabited islands in the Thousand Islands. • Compost Planting and Urban Plantation (Urban Farming) can be reduced the waste by 40-60 kg/day on the dimensions of the planting compost pit, which is 2m x 1m x 50 cm, with an average of 10 holes / island, so reduce 400–600 kg of waste/day. • Ecobricks with condensing plastic waste into plastic bottle media so that the bottles become hard and dense to use become a border decoration benches, tables and miniature ship ornaments. Inorganic waste was successfully reduced by 0.75–2 kg. • Hazardous and Toxic Materials (B3) and E-Waste is transported by ship to the Jetty in Jakarta and transported by special trucks for further management. • Residual Garbage Transportation for waste is difficult to recycle so it is brought by the Seribu Islands LH Sub-Department ship to TPST to do processing. The number of repetitions is around 3-10 times / month. • Garbage Bank, there are 24 Garbage Banks in 24 RW of Thousand Islands. • Maggot Bioconversion, there are 11 maggot houses in the Thousand Islands Administrative District. • Composting, currently the amount of organic waste reduced by the composter bin is 3,229,102 kg.

8.	February, 2020	Islands Small on Aceh Island		The unavailability of landfills in the village and on the beach as well as the lack of public awareness and the habit of disposing of waste directly into the environment (the indifference to the importance of cleaning the sea is the reason for the accumulation of waste on the sea coast of Aceh Island).
9.	Dyah et al., 2020	Harapan Island , Thousand Islands	1,552	Garbage on Harapan Island has generally been handled properly since 2017. • Waste management on Harapan Island starts from TPS, where waste is sorted between organic and inorganic waste. Organic and non-organic waste is processed in the L-Box, and the residue from the L-Box processing is transported by the Samtama Ship. • Waste that still looks good is recycled as an example for eco-bricks. • Since 2012 a Garbage Bank has been formed. • Home organic waste processing (vegetables and fruit) is used as maggot feed, composter, liquid fertilizer, solid fertilizer and planting compost. • In general, 75% of waste processing on Harapan Island is processed on the island, 25% is transported by ship.
		Pramuka Island, Thousand Islands	16	• The 2 units of L-Box incinerators which function to burn waste have no longer functioned since 2018 . • Since 2018, Pramuka Island's waste has only been sorted at TPSS before boarding the Laut Bersih ship and then taken to the Bantar Gebang TPA (however, the waste is mixed again when it arrives at the TPS). • 75% of people throw garbage into landfills, 15% to TPS, 5% to the sea and 5% use garbage.
10.	Prabawa et al., 2020	Karimunjawa Islands, Jepara Regency	7,120	• SOP for collecting data on the type and amount of plastic-based items brought aboard by residents and tourists who go to sea, then when they return, they must report the same amount of waste. • Karimun Jawa does not yet have a special agency appropriate and integrated waste management, along with its implementation program. • There is a problem of marine debris that has not received a solution and can be overcome.
11.	Arya et al., 2021	Balang Lompo Island, Pangkajene Islands Regency	0.022319	• The lack of facilities in waste handling is one of the factors that makes people's participation less . • Residents of Balang Lompo Island are not used to sorting waste before disposal. • There is a habit of people throwing garbage carelessly and openly (such as throwing garbage in the sea).

12.	Mulyan & Hidayatullah, 2021	Maringkik Island , East Lombok Regency	6	• Garbage has not been managed properly so that it has a negative impact on the comfort of residents, environmental health and the image of tourist visiting areas. • Residents still have the habit of throwing garbage on the seafront and cliff edges. • The waste management is still low. • Lack of infrastructure to process waste properly. • The local government has prepared a number of trash cans at various settlement points, but they are not in accordance with the volume of waste that is there and are even in a damaged condition.
13.	Fachry, 2021	Kapoposang Island, South Sulawesi	1,000	• Geographical conditions on the island which are bordered by the sea, become an obstacle for the local government to accommodate and dispose of community waste to land areas, so that the sea is still the final waste disposal site for the community. • The existence of the PKK program is an effective medium for increasing public knowledge and awareness about environmental hygiene, including waste management. • The development of marine environmentalist youth groups has become a medium for increasing people's knowledge and behavior not to throw garbage into the sea. • The village government has attempted to recycle waste in the form of training, but it has not touched all of the community, only about 12% of the community has attended waste management training. • Product carried out by the PKK has no economic value, which has resulted in a decrease in the community's interest in managing RT waste .
14.	Cahyadi et al., 2021	Tunda Island, Serang Regency	257.5	There is quite a lot of trash on Tunda Island and it is still not handled properly.
15.	Adicita et al., 2022	Island Lengkang, Batam City		• 99.92% of the waste on Lengkang Island is not processed, where this waste will end up in the sea. • The average amount of waste in the sea waters of Lengkang Island is 19.5 ±3.7 kg/m^2. As much as 64% of the waste that is dumped into the sea is plastic waste, and the rest consists of paper/cardboard, rubber and wood.
16.	Anna et al., 2023	Pramuka Island , Thousand Islands	16	• *Knowledge sharing* was carried out with garbage activist NGOs, showing that community awareness has begun to increase marked by the existence of the Green Literacy House.

				• Green Literacy House is an institution founded by residents on Pramuka Island that has local waste management. • At this location, waste is sorted and then made into handicrafts (bags and souvenirs) ecobrick, garden decoration and plant fertilizer for organic waste. • One of the innovations currently being developed is how waste is converted into diesel fuel using pyrolysis techniques.
17.	Wahyudi et al., 2023	Lemukutan Island, Bengkayang Regency	12,250	• Waste storage for Lemukutan Island Tourism Object is mixed between wet and dry waste, where garbage collection is still done individually. • Individual trash bins are prepared by each innkeeper and homeowner, but communal trash containers at tourist attractions are not yet available. • Management at tourist objects has not been managed properly . • Garbage is processed by burning without waste segregation. • Garbage Disposal Sites (TPS) but not operating properly.

Source: Online search with the keyword "Waste Management in Small Islands in Indonesia" (2018-2023)

Based on several articles that have been reviewed from 14 articles published from 2018-2023, with 15 islands that were used as research objects namely Pramuka Island, the Thousand Islands (Anna et al., 2023; Dyah et al., 2020; Nasution & Tjahjani, 2019), Kodingareng Lompo Island, Small Island Makassar City (Birawida et al., 2018), Kumo and Kakara Islands, North Halmahera Regency (Dobik, 2018), Lengkang Kecil Island, Batam City (Prajati & Widiantoro, 2019; Adicita et al., 2020), Untung Jawa Island, Thousand Islands (Darwati, 2019), Lengkang Island, Batam City (Adicita et al., 2020), Thousand Islands Administrative Region (Hartono, 2020), Small Islands on Aceh Island (February, 2020), Harapan Island, Thousand Islands (Dyah et al., 2020), Karimunjawa Islands, Jepara Regency (Prabawa et al., 2020), Balang Lompo Island, Pangkajene Islands District (Arya et al., 2021), Maringkik Island, East Lombok Regency (Mulyan & Hidayatullah, 2021), Kapoposang Island, South Sulawesi (Fachry, 2021), Tunda Island, Serang Regency (Cahyadi et al., 2021), Lengkang Island, Batam City (Adicita et al., 2022) and Lemukutan Island, Bengkayang Regency (Wahyudi et al., 2023), waste management on small islands in Indonesia found different findings on each island. There are several islands where waste management has been well coordinated starting from the container to its destruction, but there are also found waste that ends up being dumped into the environment, especially the sea. This can be caused by several factors such as the lack of waste management facilities, geographical conditions that are surrounded by the sea making it easier to dispose of waste into the sea and the low level of community participation and awareness regarding the importance of protecting the environment from waste.

As with Pramuka Island which is in the Thousand Islands administrative area, based on research conducted by Nasution & Tjahjani (2019) found that some waste management has gone through the process of container, processing, collection and destruction quite well (although there are still several processes that must be evaluation such as sorted containers), but unfortunately 70-80% of the waste produced still ends up being dumped into the sea and around settlements. In 2020, research was conducted again by Dyah et al. in Pramuka Island, found that the incinerator unit used for waste destruction was no longer operating, so the waste was only sorted before being transported by the Clean Sea Ship to the Bantar Gebang TPA. However, the percentage of people who throw garbage into the sea has decreased to 5%, 75% of people throw garbage into landfills, 15% to TPS and the remaining 5% use waste to make handicrafts. Other findings in research conducted by Anna et al., (2023) on Pramuka Island, found that there was an increase in community awareness after sharing knowledge with NGOs with the formation of the Green Literacy House which was founded by residents on Pramuka Island who have local waste management. At this location waste is also sorted and then made into handicrafts (bags and souvenirs), ecobrick, garden ornaments and plant fertilizer for organic waste. One of the innovations currently being developed is how waste is converted into diesel fuel using pyrolysis techniques.

Another island in the Thousand Islands administrative area, namely Untung Jawa Island, based on research conducted by Darwati (2019) found things that were not much different from the results of research by Dyah et al. (2020) on Pramuka Island, namely sorting and storage, but not processed in an incinerator because it is no longer functioning, then transported to Jakarta by ship or stockpiled in residents ponds to be burned if the transport ship does not arrive.

Different findings from research conducted by Hartono (2020) in the Thousand Islands Administrative region, found that there were good efforts being made by the Seribu Islands Administrative District Environmental Service, such as destroying organic waste through an L-Box incinerator (destroying 300–1,100 kg/day), planting compost and urban gardening (reducing 400–600 kg of waste/day), composting (reducing 3,229,102 kg of waste), ecobrick (reducing waste by 0.75–2 kg), there are 24 waste banks and 11 maggot

house. Meanwhile for residual waste taken by the Thousand Islands LH Sub-dept. Ship to TPST for processing and transport of Hazardous and Toxic Materials (B3) and E-Waste by ship to the Jetty in Jakarta and transported by special trucks for further management.

Research conducted by Dyah et al. (2020) on Harapan Island, Thousand Islands also found the same thing as the findings in a research conducted by Hartono (2020) , that waste on Harapan Island in general has been handled quite well, as waste has been handled starting from sorting at TPS between organic waste and inorganic to be processed in the L-Box and the residue is transported by the Samtama Ship. Plastic waste that still looks good is recycled for eco-bricks, organic household waste (vegetables and fruit) is used as maggot feed, composter, liquid fertilizer, solid fertilizer and planting compost and since 2012 a Garbage Bank has been formed. In general, 75% of waste processing on Harapan Island is processed on the island, 25% is transported by ship.

Meanwhile research was conducted on Lengkang island, Batam city (Adicita et al., 2020, 2022), Kodingareng Lompo island, Makassar city (Birawida et al., 2018), small islands on Aceh Island (Febri, 2020), Karimunjawa Islands (Prabawa et al., 2020), Kumo and Kakara islands, North Halmahera (Dobik, 2018), Balang Lompo islands (Arya et al., 2021), Maringkik islands, East Lombok (Mulyan & Hidayatullah, 2021), Lengkang Kecil island, Batam city (Prajati & Widiantoro, 2019), Kapoposang island, South Sulawesi (Fachry, 2021), Tunda island, Serang district (Cahyadi et al., 2021) and Lemukutan island (Wahyudi et al., 2023), found that the condition of waste management had not been handled properly. Most of the people still throw their garbage into the sea. As happened on Lengkang Island where 99.92% of the waste was not processed and ended up in the sea. Likewise what happened on Kodingareng Island, where 98.9% of the waste collected will be disposed of into the sea.

The factors that contributed to the unmanageable waste on several islands were due to:

1. Geographical conditions on the island bounded by the sea
   This can become an obstacle for the local government to accommodate and dispose of community waste to land areas, so that the sea is still the final waste disposal site for the community. In addition, the sea is an easy means of disposal for the community.
2. Lack of waste management facilities
   The lack of facilities in waste handling is one of the factors that makes people's participation less. In fact, on several islands there are still no good waste management facilities so that the sea becomes a target community as a disposal site rubbish. In addition, the absence of temporary waste collection facilities (TPS) causes people to dispose of waste in their own yards or throw it directly into the sea. In addition there are also islands that do not have a special agency appropriate and integrated waste management, along with its implementation program.
3. Limited land area on small islands
   The size of the Waste Disposal Site (TPS) also causes the condition of the size of the TPS to not operate properly because the TPS cannot accommodate the volume of waste that exists.
4. Low awareness and community participation in waste management
   People are not used to sorting waste before disposal. As found on the island of Kodingareng , where not a single community does their household waste sorting. In addition, the low skill level of residents for waste management is also the reason why waste ends up in the sea or is only processed by burning or landfilling without waste segregation. As was found on the island of Lengkang Kecil, where the islanders would only move to dispose of the garbage that had accumulated when the smell of the garbage was very disturbing.

Meanwhile, waste management based on the industrial revolution 4.0 in question is waste management that involves the application of digital technology and connectivity in waste collection, sorting, recycling and processing systems to create smarter, more efficient and sustainable solutions (Tchobanoglous et al., 2014). Industrial Revolution 4.0-based waste management involves the application of digital and communication technology to create an integrated, monitored and connected system for collection, transportation, sorting, recycling and sustainable waste disposal (Mohamed et al., 2021). Industrial Revolution 4.0-based waste management includes the use of sensors, IoT, and data analytics to monitor, manage, and optimize the entire waste management cycle, including collection, sorting, recycling, and final disposal (Camarinha-Matos et al., 2019). In practice, waste management is also carried out by real-time data collection, intelligent data analysis and automation systems to optimize waste collection, sorting and processing in a more efficient and sustainable way (Zaman et al., 2019).

The things mentioned above have not been seen in the waste management carried out in small islands in Indonesia. The use of technology used in waste management is carried out only in the process of destroying waste using an L-Box incinerator in the Thousand Islands Administrative area (Hartono, 2020), another innovation being developed at this time is how waste is converted into diesel using the pyrolysis technique (Pramuka Island, Anna et al., 2023). Beyond that, waste management is only limited to container, collection, transfer/processing and final processing or bringing it to land which has a processing site for further management. Most people also still throw their garbage into the sea and around settlements. The application of digital technology and communication to create an integrated, monitored and connected system for the collection, transportation, sorting, recycling and disposal of sustainable waste is still very far from the waste management carried out by the small islands in Indonesia which are the object of this research.

Therefore, the government's role is needed to support waste management on these small islands and encourage the independence and awareness of small island communities in managing waste in order to create integrated and sustainable industrial revolution-based waste management 4.0 to overcome environmental pollution caused by this waste. Like the findings conducted by Hartono (2020) in his research on the Thousand Islands Administrative Region which can be an example of waste management that can be applied to other small islands in Indonesia, even though an integrated 4.0 basis and digital technology cannot yet appear on the island.

Conclusion

Based on the findings obtained from 14 articles published from 2018-2023, with 15 islands as research objects, it was found that most of the small islands used as research objects still had not carried out proper waste management. The waste that is produced ends up being dumped into the sea, so that the pile of garbage in the sea is inevitable. The factor of unmanaged waste on several islands can be caused by geographical conditions on islands bordered by the sea , lack of waste management facilities, limited land area on small islands and low public awareness and participation in waste management. The rest, several islands have carried out the process of storage, processing, collection and destruction quite well. Also at that location , waste is sorted and then made into handicrafts (bags and souvenirs), ecobrick, garden ornaments and plant fertilizer for organic waste as well as the development of innovations on how waste can be converted into diesel fuel with pyrolysis techniques.

The application of industrial revolution-based waste management 4.0 has also not been seen in waste management on small Indonesian islands which are the object of this

research. This can be input for the government and managers to create waste management on small islands in Indonesia that is integrated and digital technology in order to reduce waste generation on land and waste contamination in the sea. The participation of the community and Non-Governmental Organizations (NGOs) is also very much needed in the success of waste management on these small islands.

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