Environment and Natural Resources Journal

Volume 23
Issue 5
2025

Strategy of Implementing Incinerator for Port Solid Waste Management: Case Study of Tanjung Luar Fishing Port, Indonesia

Mustaruddin[1*], Iin Solihin[1], Gondo Puspito[1], Syifa Nurul Aini[2], Eko Sri Wiyono[1], and Fis Purwangka[1]

[1]Department of Fishery Resources Utilization, Faculty of Fisheries and Marine Sciences, IPB University, Bogor, Indonesia
[2]Department of Resource and Environmental Economics, Faculty of Economics and Management, IPB University, Bogor, Indonesia

ARTICLE INFO

Received: 15 Jan 2025
Received in revised: 20 May 2025
Accepted: 26 May 2025
Published online: 16 Jul 2025
DOI: 10.32526/ennrj/23/20250020

Keywords:
Environment/ Fishing/ Fishing boat/ Fishing port/ Port industry/ Solid waste

*** Corresponding author:**
E-mail:
mustaruddin@apps.ipb.ac.id;
mus_m03@yahoo.com

ABSTRACT

The study aimed to (a) analyze fisheries' activities and the suitability of incinerators for port solid waste management, (b) formulate priority strategies for implementing incinerator technology in Tanjung Luar Fishing Port. The methods used were descriptive analysis, score methods, and Analytic Hierarchy Process (AHP) methods. The developing fishery activities analyzed in Tanjung Luar were fishing boat activities, fish marketing, port industries and fish processing, sea supply kiosk, provision of sea fuels, provision of ice for fish, food stalls, and other fishery services. The suitability of incinerators for port solid waste management was relatively high, which was indicated by the fulfillment of 'good compliance' criteria (3.20 on a scale of 1-4) and 'very good beyond compliance' criteria (3.52 on a scale of 1-4). Developing an environmental control system in incinerator operations (CONT) was priority strategy I of implementing incineration into solid waste management in fishing ports (IR=0.245, inconsistency 0.05). The supporting strategy was the recruitment of skilled incinerator managers from the community (MANG) (IR=0.232, inconsistency 0.05). The implementation of incinerators is believed to be able to save the management cost of port solid waste reaching 26,584.62 USD per year, prevent waste hazards to fish caught, fisheries actors, visitors, and the community around the port (9,768 people), and improve the performance of fishery activities in the port (8 activities). In the future, it is hoped that research will be conducted on the development of energy sources for fishing ports that utilize combustion heat in incinerators.

HIGHLIGHTS

This study highlights fishery activities in a fishing port and the potential for solid waste produced. Furthermore, it analyses the suitability of incinerators if applied to manage the port's solid waste. Finally, it formulates a priority strategy for implementing incinerator technology after it is declared suitable for the Fishing Port.

1. INTRODUCTION

Fishing ports are the centre of fisheries activities in many regions in Indonesia. This is because fishing ports are a place for unloading fish caught by fishing boats, a place where fish processing industries obtain raw fish, a place where fish marketing activities are carried out, and a place where supporting fisheries businesses develop. One of the fishing ports that plays this role is the Tanjung Luar Fishing Port (FP), East Lombok Regency. According to the Department of Marine Affairs and Fisheries (DMAF) of East Lombok Regency (2024), the Tanjung Luar FP was the main centre of fisheries activities in West Nusa Tenggara (WNT) Province, where fish production reached 4,382 tons/year or 58.66% of the total marine fish production in 2023 in East Lombok Regency. Meanwhile, East Lombok Regency mainly contributed to WNT's fisheries and marine products (Mustaruddin et al., 2022a; Firdaus et al., 2020).

However, these fishery activities also had a negative impact on the environment of the fishing port, namely producing various solid, liquid and gas waste. Solid waste was the type of waste that most

Citation: Mustaruddin, Solihin I, Puspito G, Aini SN, Wiyono ES, Purwangka F. Strategy of implementing incinerator for port solid waste management: Case study of Tanjung Luar Fishing Port, Indonesia. Environ. Nat. Resour. J. 2025;23(5):409-419. (https://doi.org/10.32526/ennrj/23/20250020)

produced by fishery activities at Tanjung Luar FP. According to the Department of Environment and Sanitation (DES) of East Lombok Regency (2024), almost all fishery activities at the Tanjung Luar FP produced solid waste. The activities of fishing vessels, fish marketing, and sea supply kiosks were the main contributors of solid waste, especially from net scraps, used containers and plastics, leftover supplies, fallen fish, and fish pieces (Shofa and Hadi, 2017; Subhan, 2018; Liu et al., 2022). Solid waste at the Tanjung Luar FP also comes from community activities around the port. Meanwhile, liquid and gas waste generally come from fisheries processing and transportation activities, but the amount is not as much as solid waste. The volume of daily solid waste at the Tanjung Luar FP tends to increase, and its condition is concerning because it has spread to the port ponds. In 2022, a cleaning activity for the port and coastal area involved fisheries stakeholders, village trustee army, and the community. In 2023, DES of East Lombok Regency carried out a marathon garbage sweeping activity in the coastal and port areas (DMAF of East Lombok Regency, 2024). However, these activities were limited to collecting and sorting waste, but no waste processing system in place. As a result, the solid waste/garbage that had been collected spread again and polluted the fishing port area.

One effort that can be made in aim to solve the solid waste problem is to apply incinerator technology. An incinerator is a solid waste processing technology that is operated at high temperatures. This temperature is produced by developing a closed combustion technique, where heat is optimised for burning and nothing is released into the environment (Ji et al., 2022; Yang et al., 2019). This incineration technique is considered suitable for solid waste from fishing ports, which are usually wet, contain lots of used sacks, pieces of containers, fish scraps/pieces, net scraps, fibres, and plastic packaging (Liu et al., 2022; Hendrawan, 2022). The organic and inorganic components in the waste are mixed, wet, with various sizes that are difficult to separate. This will complicate the application of other technologies, such as composting and bio-digesters. These two technologies only process organic waste from fish scraps and food waste, while used sacks, net scraps, fibre and plastic packaging cannot be processed (Subhan, 2018; Ozkaynak and Icemer, 2024; Vaio et al., 2019). Incinerator technology can process all types of solid waste. However, in order to be widely operated, waste processing technology must meet the proper criteria stated in Ministry of Environment and Forestry (MEF) of Indonesia (2021) and be well received by local fisheries stakeholders (McClanahan et al., 2024; Caramuta et al., 2021).

The study helps to ensure this, thus facilitating the implementation of incinerator technology in the Tanjung Luar FP area. The study aimed to (a) analyse fishery activities and the suitability of incinerators for solid waste management at the fishing port, and (b) formulate priority strategies of implementing incinerator technology for solid waste management in fishing ports.

2. METHODOLOGY

2.1 Study location

The location of the study was the Tanjung Luar FP Area, East Lombok Regency, WNT Province, Indonesia (Figure 1). The study was conducted in June-August 2024.

2.2 Data collection

The data collected consisted of fisheries activity data, dominant fish landed data, solid waste data, incinerator suitability data for solid waste management, and views regarding the application of incinerators for port solid waste management. Statistics collection methods included field exploration, questionnaire distribution, training, and focus group discussions (FGD). Field exploration was intended to collect information on fisheries activities and dominant fish landed at the Tanjung Luar FP. The distribution of questionnaires was designed to collect information on solid waste and the suitability of incinerators for their management. Training and FGD were intended to raise awareness of waste management while obtaining information/views regarding the application of incinerator technology for port solid waste management. Training and FGD were carried out by combining the concepts of the classroom and field method. This combination of methods was used to optimise the impact of awareness and the depth of information obtained from FGD participants.

Questionnaire respondents and FGD participants were selected purposively from fisheries stakeholders who are active in the Tanjung Luar FP Area. The selection criteria were active fisheries actors who have been active in the Tanjung Luar FP Area for at least two years. Specifically for questionnaire respondents, added with minimum education criteria of junior high school graduates (Ozkaynak and Icemer, 2024; Kamargo et al.,

2018). The questionnaire respondents amounted to 15 people consisting of 4 fishermen, 3 fish industry/ processors, 3 fish traders, 3 supporting service actors, and 2 port managers.

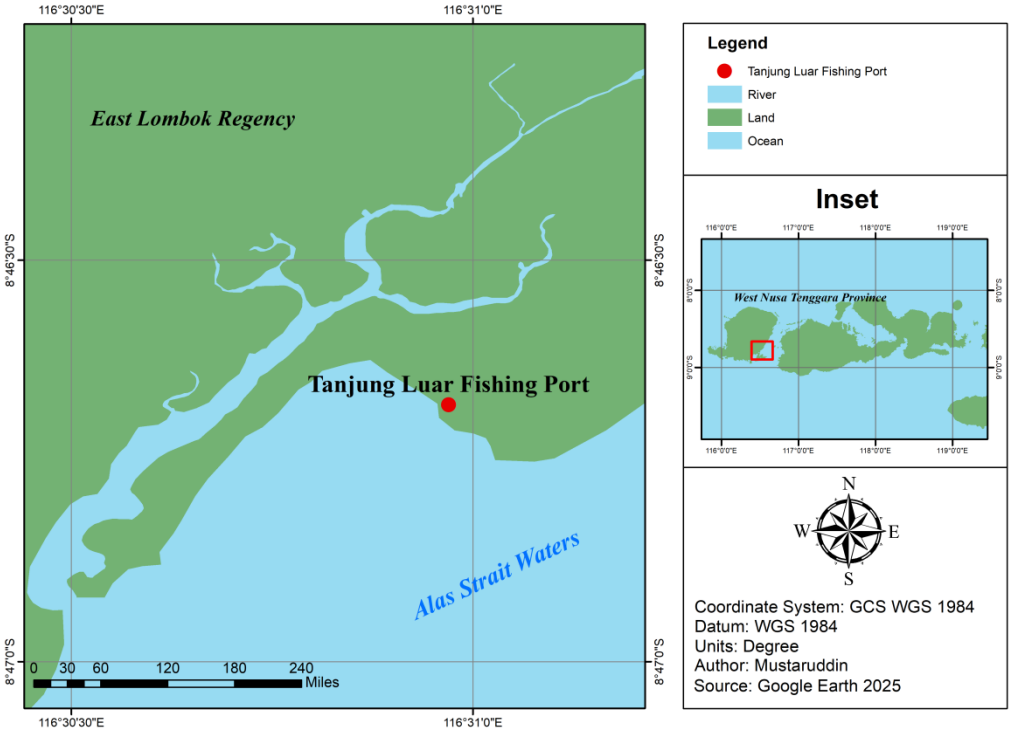

Figure 1. Map of the study area

2.3 Data analysis

Data analysis used descriptive analysis, score methods, and analytical hierarchy process (AHP) methods. Descriptive analysis was used to describe fisheries activities in the Tanjung Luar FP Area and the potential solid waste they generate. Score methods were used to evaluate the suitability of incinerators with proper criteria for port solid waste management. According to MEF of Indonesia (2021), there were two proper criteria, namely compliance criteria and beyond compliance criteria. Aspects assessed in the compliance criteria include water pollution control, air pollution control, toxic and hazardous waste management, and control of potential land damage. Beyond compliance criteria include energy efficiency efforts, implementation of reduce, reuse and recycle (R3), protection of biodiversity, and community development programs.

The AHP method was used to formulate priority strategies for the application of incinerator technology in the management of fishery port solid waste. According to Mustaruddin et al. (2011) and Caramuta et al. (2021), the AHP method is divided into four analysis hierarchies, namely goals, criteria, sub-criteria (optional), and alternative strategies. In this study, the goal was the strategy of implementing incinerator technology for solid waste management in fishing ports. The criteria used were compliance criteria and beyond compliance criteria. Sub-criteria were not developed because the substance of both criteria was complete and accommodated applicable regulations (MEF of Indonesia, 2021). Alternative strategies were further determined from the results of FGD and questionnaire distribution. Analysis of each hierarchy used a paired comparison test (Saaty, 1993). Furthermore, the results of the AHP analysis were tested for inconsistency and sensitivity. The results of the AHP analysis could be trusted if they have an inconsistency <0.1 and are not too sensitive (Mustaruddin et al., 2011).

3. RESULTS AND DISCUSSION

3.1 Fishery activities and solid waste potential at the Tanjung Luar Fishing Port

Fishery activities at the Tanjung Luar FP generally supported the production of fish docking at the port. These activities consisted of fishing boat activities, fish marketing, port industry and fish processing, provision of supplies for going to sea at supply kiosks, provision of fuel for going to sea,

provision of ice for fish, food stalls, and other fishery services. The dominant fish landed were squid, yellowtail, sardinella, pinkear emperor, selar, cob, mackerel tuna, and bullet tuna (Table 1). This fishing was generally carried out by small fishermen who operate outboard motorboats (DMAF of East Lombok Regency 2024). This type of boat is widely chosen because of more flexible in its operation. Larger boats are rare and are used for fishing in more distant waters, such as the waters of Sumbawa Island and the waters of East Nusa Tenggara.

Table 1. The dominant fish landed at Tanjung Luar Fishing Port

No	Fish species	Semester 1 in 2023 (kg)	Semester 2 in 2023 (kg)	Total (kg)	Potential waste of fishing
1	Squid (*Loligo chinensis*)	24,742	357,966	382,708	squid pieces (tentacles), fishing line pieces
2	Yellowtail (*Paracaesio kusakarii*)	164,943	5,230	170,173	bait scraps, fishing line pieces
3	Sardinella (*Sardinella albella*)	14,616	219,675	234,291	fallen fish, net scraps
4	Pinkear emperor (*Lethrinus amboinensis*)	312,809	39,646	352,455	fallen fish, net scraps, fishing line pieces
5	Selar (*Selar crumenophthalmus*)	5,315	161,865	167,180	fish pieces, net scraps
6	Cob (*Auxis thazard*)	14,074	164,994	179,068	fish pieces, scales and guts, net scraps, fishing line pieces
7	Mackerel tuna (*Euthynnus affinis*)	36,508	200,810	237,318	fish pieces, scales and guts, net scraps
8	Bullet tuna (*Auxis rochei*)	68,777	374,802	443,579	fish pieces, scales and guts, net scraps

Source: data processed from DMAF of East Lombok Regency (2024)

In semester 1 (January-June), the fish that were caught the most were yellowtail (*Paracaesio kusakarii*) and pinkear emperor (*Lethrinus amboinensis*). This is thought to be because in semester 1, the frequency of rain is higher (rainy season), so that the salinity of sea water is lower and many nutrient components from land enter the waters. Yellowtail and pinkear emperor are types of reef fish that like low salinity and inhabit sandy areas with lots of coral (Kamargo et al., 2018; Wahyudin et al., 2019). Nutrients carried by floods from land will settle at the bottom of the waters and accelerate the increase in the population of both types of fish. In semester 2 (July-December), squid production increased drastically, allegedly due to longer sunlight (dry season) in those months. Mustaruddin et al. (2022a) and Rosalina et al. (2011) argued that squid prefer shallow waters with dim lighting. In these conditions, squid will grow large and reproduce rapidly. This encourages increased fish production and increased fishing activities in the Tajung Luar FP, while increasing the amount of waste produced.

The solid waste generated by fishing activities was very diverse, including net scraps, fallen fish, used cardboard, used plastic, fish container waste, used sacks, used styrofoam, pieces of rope, and food waste (Table 2). The diversity of the waste was influenced by the scope of the business and the type of demand received by fishery business actors/stakeholders in the Tanjung Luar FP area. The results of distributing questionnaires and FGDs stated that the potential for solid waste tends to increase from year to year due to the increase in fish landing services and variations in needs in fishing, fish processing, and fish marketing. The waste was generally wet because it came from handling fresh fish, cooling fish, providing ice, and handling processed fish, especially salted fish. Fresh fish and salted fish are the main products produced in the Tanjung Luar FP area (Mustaruddin et al., 2022a; Firdaus et al., 2020).

Currently, solid waste at Tanjung Luar FP (Table 2) has not been handled optimally. The local authorities only handled around 37% of the waste, by taking it to the waste disposal site. The rest was just piled up, then scattered again until it enters the port pool. This continued to happen until it became news in many mass media (Subhan, 2018; DES of East Lombok Regency, 2024). Cleaning efforts were carried out, for example through cleaning activities for the port and coastal areas in 2022, and marathon sweeping of coastal and port waste in 2024 (DMAF of East Lombok Regency, 2024). However, these activities were not carried out routinely, so that solid waste to the port continued to spread and pollute the environment.

Table 2. Fishery activities and solid waste potential at Tanjung Luar Fishing Port

No	Fishery activities	Products/services	Potential solid waste
1	Fishing boat	fish caught	net scraps, fishing line pieces, used cardboard supplies, used plastic, fallen fish, pieces of fish, fish guts
2	Fish marketing	fish caught	fish tank waste, fallen fish, fish guts, pieces of rope
3	Port industry and fish processing	loading and unloading fish, processed fish	waste from fish landing, fish handling, fish containers, spice containers, fish pieces, fish scales and guts, leftover burning wood
4	Sea supply kiosk	fishing supplies	used cardboard, wooden crates, used sacks, leftover packages
5	Provision of fuel	fishing fuel	used jerry cans, pipe pieces and used hoses
6	Provision of ice for fish	Ice for fishing	leftover ice containers, used styrofoams
7	Food stalls	ready to eat food	used cardboard, used plastic, leaves, leftover food, leftover packages
8	Fishery services	fish handling and transportation	used cardboard, used spare parts, pieces of rigging

3.2 Suitability of incinerators for port solid waste management

An incinerator is a waste processing technology developed to overcome the problem of solid waste in the field, especially if the waste is wet and has various sources. The incinerator proposed in this study is a closed combustion type whose combustion heat can be increased to 800-1,200ºC. The incinerator components were initiated to be installed vertically. The goal is that it can be operated in fishing ports with narrow land and can be moved. The vertical installation is intended so that the incinerator does not take up much space for fisheries activities in the port. This is because the activity zone is already full at Tanjung Luar FP. The incinerator that was initiated has a capacity of 15-20 tons/day. This capacity is more than enough to handle solid waste from the fishing port and its surroundings which reaches 12-15 tons/day. However, the development of incinerators in fishing ports must meet the proper criteria required in MEF of Indonesia (2021). It is important so that the incinerator can be operated properly on site, its utilization level is optimal, and it is safe for the environment (Cheng et al., 2020; Thanassekos and Scheld, 2020; Hendrawan, 2022).

Figure 2 presents the distribution of incinerator suitability values for solid waste management in the Tanjung Luar FP area, and Figure 3 presents the level of fulfillment of the required compliance criteria and beyond compliance criteria. The values is scaled from 1 to 4, where values 1, 2, 3, and 4 mean bad, moderate, good, and very good respectively.

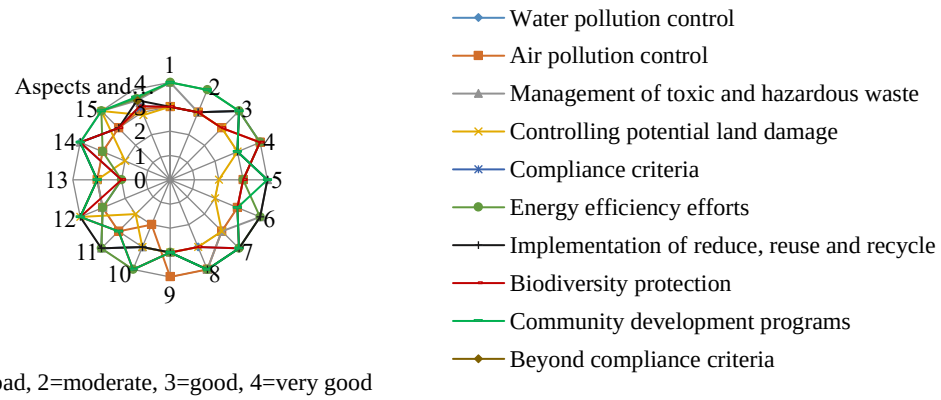

Figure 2. Distribution of incinerator suitability values for solid waste management in the Tanjung Luar Fishing Port Area.

Based on Figure 2, solid waste management with incinerators had received quite diverse responses from fisheries stakeholders, but no one gave a bad score. This shows that there was no social rejection of incinerators (Ji et al., 2022; Osmundsen, 2023). The incinerator technology also met the compliance criteria good (3.20 on a scale of 1-4) and the beyond compliance criteria very good (3.52 on a scale of 1-4) for application in fishing ports (Figure 3). This shows that incinerators could be widely applied for solid

waste management in the Tanjung Luar FP area. In the compliance criteria, the aspect that was met very good was water pollution control (3.53 on a scale of 1-4). In the beyond compliance criteria, the aspects that were met very good were energy efficiency efforts, implementation of reduce, reuse, and recycle (R3), and community development programs with values of 3.60; 3.53; and 3.67 on a scale of 1-4, respectively. The only aspect with a relatively low value was controlling potential land damage (2.87 on a scale of 1-4). In the implementation of R3, the reduction aspect could be optimised because the incinerator could reduce the volume of solid waste by up to 70% (Ji et al., 2022; Hendrawan, 2022). Ash from the burning of used cardboard, fallen fish, leftover food, used wooden crates, and fish pieces can be used as fertiliser (recycle) in greening at Tanjung Luar FP and its surroundings.

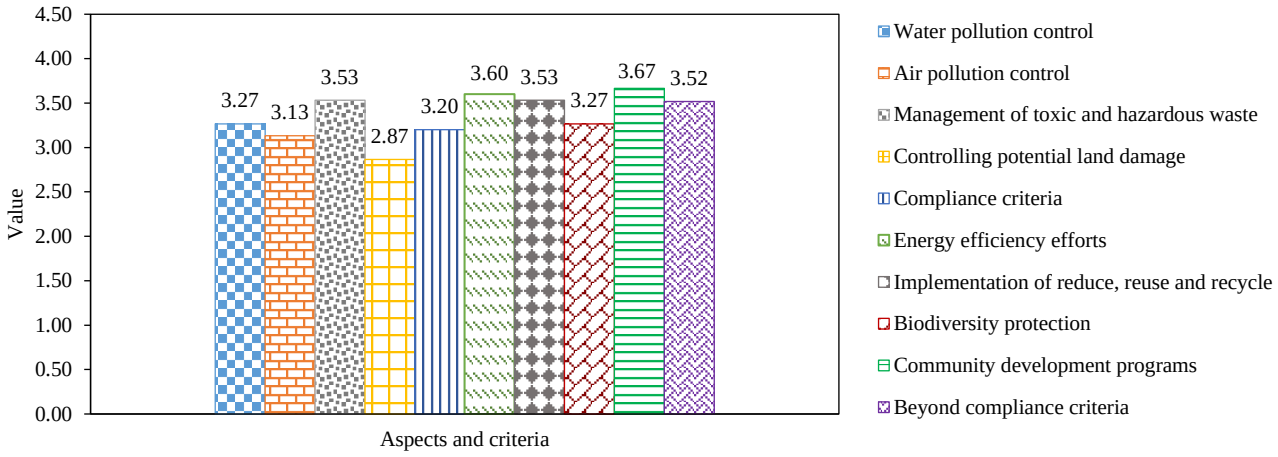

Figure 3. Compliance of incinerator technology with respect to compliance and beyond compliance criteria for application in fishing ports.

The highest value in the community development aspect was thought to be because the incinerator opens great opportunities for the involvement of fishermen, port industry and fish processing players, fish traders, and supporting service actors at the port, especially in sorting solid waste and operating the incinerator. Fisheries stakeholders can bring their waste/garbage, although not too dry, because the incinerator is designed to operate with high combustion heat (Yang et al., 2019; Ji et al., 2022). The operation of the incinerator is also relatively easy and is closed combustion, so the risk of accidents can be minimised (Shofa and Hadi, 2017; Cheng et al., 2020). The value in the aspect of controlling potential land damage (Figure 3) was not high but was quite good. This was because the application of the incinerator was only focused on the port area (not on a large area). However, fishery activities at the Tanjung Luar FP were very complex (Table 2) and occur every day (DMAF of East Lombok Regency, 2024), so the volume of waste remained high. Fishery activities at the Tanjung Luar FP were always busy because it was the main destination for fish landings from boats operating in the Alas Strait waters and many other waters in WPPRI-573 (Firdaus et al., 2020; Mustaruddin et al., 2022a).

3.3 Strategy of implementing incinerator technology for port solid waste management

The success of implementing incinerator technology in the Tanjung Luar FP Area was greatly influenced by the strategy chosen. Therefore, the alternative strategies offered in the study come from the aspirations and interests of fisheries stakeholders in the location. These alternative strategies were: (a) Recruitment of skilled incinerator managers from the community (MANG), (b) Development of appropriate incinerators collectively (COLL), (c) Cooperation in incinerator development with private companies (COOP), (d) Development of environmental control systems in incinerator operations (CONT), and (e) Development of tariff systems in incinerator operations (TARF). In addition, the continuity of the strategy application also depended on the level of fulfilment of the strategy against applicable standards/criteria that underlie its positive assessment (Caramuta et al., 2021; Mustaruddin et al., 2022a). In this study, the criteria referred to the applicable regulations on proper (MEF of Indonesia, 2021). The

hierarchical tree for determining priority strategies is presented in Figure 4. Furthermore, the results of the analysis related to the urgency of the criteria and the achievements of each alternative strategy in meeting these criteria are presented in Table 3.

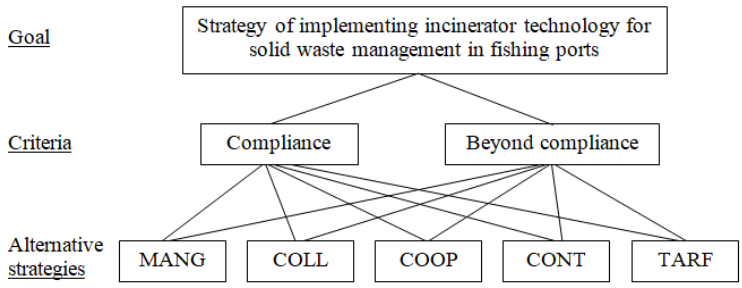

Figure 4. Hierarchy tree for determining the priority of strategy of implementing incinerator technology for solid waste management in fishing ports

Table 3. Results of the analysis of the urgency of proper criteria and the achievement of each alternative strategy in meeting these criteria

Proper criteria	Alternative strategy	IR	Achievements	Inconsistency
Compliance (IR: 0.333)	MANG	0.249	0.098	
Compliance (IR: 0.333)	COLL	0.181	0.071	
Compliance (IR: 0.333)	COOP	0.197	0.078	0.06
Compliance (IR: 0.333)	CONT	0.124	0.049	
Compliance (IR: 0.333)	TARF	0.249	0.098	
Beyond compliance (IR: 0.667)	MANG	0.222	0.134	
Beyond compliance (IR: 0.667)	COLL	0.143	0.087	
Beyond compliance (IR: 0.667)	COOP	0.191	0.116	0.04
Beyond compliance (IR: 0.667)	CONT	0.323	0.196	
Beyond compliance (IR: 0.667)	TARF	0.122	0.074	

Based on Table 3, the beyond compliance criteria were the most urgent proper criteria (IR=0.667) to be fulfilled in the implementation of incinerator technology in the Tanjung Luar FP Area. It was thought to be because the beyond compliance criteria were more accommodating to the dynamics and needs of the field, for example, related to energy efficiency and the existence of community development programs. According to Ewell et al. (2020) and Ross et al. (2024), the beyond compliance criteria pay attention to the best environmental management practices in the community and the dynamics of global environmental issues. The results of the analysis were also in line with the level of fulfilment of the incinerator in Figure 3, which prioritised the beyond compliance criteria. However, both proper criteria must still be fulfilled to support the legality and continuity of the implementation of incinerators for port solid waste management. The compliance criteria provide a portion of 33.3% (IR=0.333) for the legality of the application.

The strategy of recruiting skilled incinerator managers from the community (MANG) and the strategy of developing a tariff system in incinerator operations (TARF) met the compliance criteria good, namely with each achievement of 0.98 at a trusted inconsistency of 0.06. It is quite reasonable because skilled managers are believed to have a better understanding of applicable waste management regulations, while the tariff system is a manifestation of compliance with these regulations (Ewell et al., 2020; McClanahan et al., 2022). For the beyond compliance criteria, it was very good met by the strategy of developing an environmental control system in incinerator operations (CONT), namely with an achievement of 0.196 at a trusted inconsistency of 0.04. According to McClanahan et al. (2022), Azeez et al. (2022), and Subhan (2018), the development of an environmental control system has a major impact on protecting fish quality, public health, and the comfort of activities in the port area. The strategy of recruiting skilled incinerator managers from the

community (MANG) and the strategy of cooperation in incinerator development with private companies (COOP) also met the criteria good, with achievements of 0.134 and 0.116, respectively (inconsistency 0.04). Both strategies expanded community involvement through recruitment and cooperation programs.

By considering the urgency of each criterion and the achievement of each alternative strategy, the strategy of implementing incinerator technology for solid waste management in fishing ports could be formulated with a priority order, as presented in Figure 5.

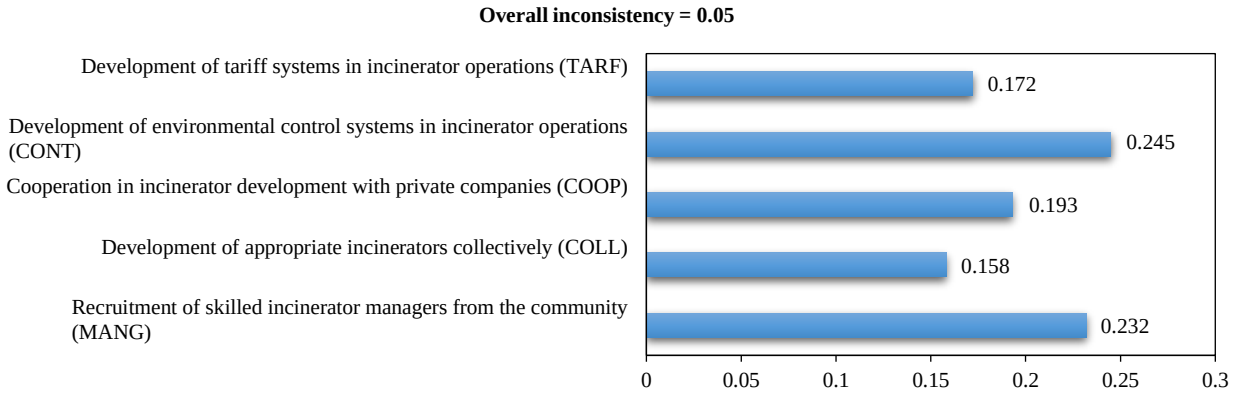

Figure 5. Analysis results of strategic priorities of implementing incinerator technology for port solid waste management

Based on Figure 5, the strategy for developing an environmental control system in incinerator operations (CONT) is a priority I (IR=0.245, inconsistency 0.05) if incinerator technology was applied in the Tanjung Luar FP area. According to Ji et al. (2022) and Liu et al. (2022), an environmental control system is very much needed in waste management because it directly controls the operations and outputs it produces. The environmental control system protects fishermen and the community from the impacts of neglected fisheries and port activities (Mustaruddin et al., 2022b; Cheng et al., 2020; Shofa and Hadi, 2017). The CONT strategy was also not too sensitive because it only changed when there was a decrease in the program's orientation towards the community (IR beyond compliance criteria <0.632), while the decrease/unclear regulations were relatively stable (Figure 6). According to Caramuta et al. (2021) and Firdaus et al. (2020), a strategy that was oriented towards community welfare needs to be prioritised because in addition to its high acceptance, it was also effective in its implementation in fishing ports.

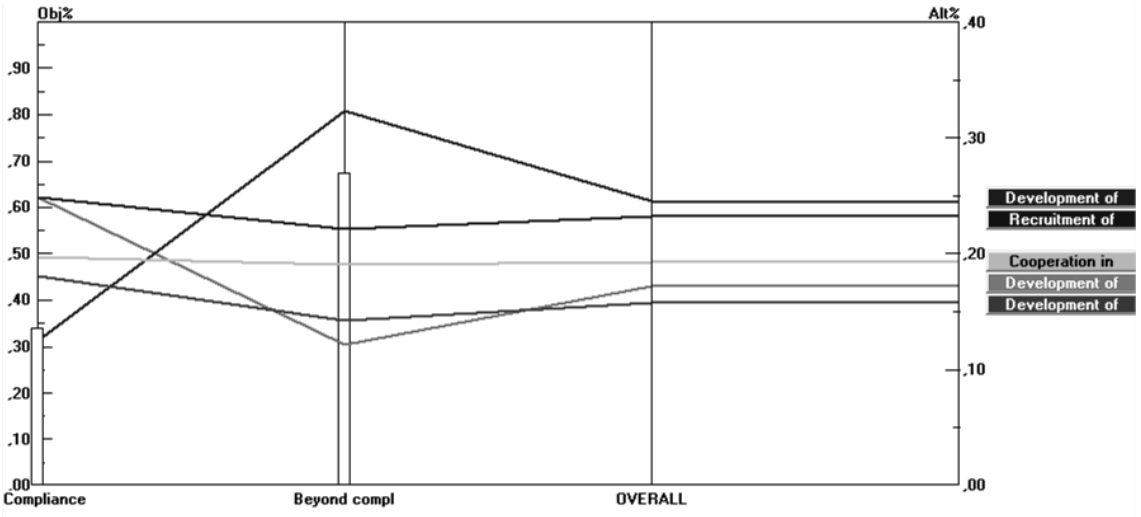

Figure 6. Results of the sensitivity analysis of the strategy for developing an environmental control system in incinerator operations (CONT) in fishing ports

The environmental control system developed in the CONT strategy can include pollution control mechanisms, emission threshold controls, and post-combustion ash cleaning. Pollution control is carried out using two mechanisms, namely: (1) turning on the incinerator when fishing port activities are quiet, and (b) planting trees in the port area and coastal areas around the port. For emissions, it can be controlled by installing an emission detection device on the incinerator. This device provides information on emission conditions when the incinerator is operated, and its operation can be suspended if emissions exceed the threshold (Ji et al., 2022; Hendrawan, 2022). Ash cleaning can be done periodically, for example, every 5-7 days. Furthermore, the ash can be used to fertilising trees that function as air pollution controllers, and the rest can be shared with the community (as organic fertiliser). This is very good because the existence of the incinerator provides additional benefits to the community. According to Caramuta et al. (2021) and Firdaus et al. (2020), strategies that have a real impact on the community need to be prioritised, because apart from being highly acceptable, their implementation will definitely be more effective in fishing ports.

The strategy of recruiting skilled incinerator managers from the community (MANG) could be a back-up (priority II) and supporter of the CONT strategy. In its application, the strategy could be carried out after the environmental control system in incinerator operations had been adequately fulfilled. The control system was an important content in training incinerator managers recruited from the community. According to Ross et al. (2024) and Ewell et al. (2020), a combination of complementary strategies can increase the chances of success of the incinerator program as a solution for handling port waste. Meanwhile, the success of the program stages can increase the trust of fisheries stakeholders (McClanahan et al., 2024; Firdaus et al., 2020) and guarantee the long-term implementation of incinerators (Yang et al., 2019; Hendrawan, 2022). Table 4 presents several implications/benefits that could arise from the implementation of incinerators for the sustainability of fisheries activities at the Tanjung Luar FP.

Table 4. Implications of the implementation of incinerators on the sustainability of fisheries activities in the port

No	Fishery activities	Contribution of fisheries stakeholders to incinerators	Implications/benefits of implementing incinerators in fishing ports
1.	Fishing boat	Collection of fishing waste, prospective incinerator operators	Clean fish landing dock, faster fish unloading, more hygienic fish caught
2.	Fish marketing	Collection of solid waste at fish auction sites, prospective incinerator operators	Image of fish caught increases, fish auction is neater and more orderly, fish sells faster
3.	Port industry and fish processing	Collection of solid waste from port industry and fish processing, prospective incinerator operators	Complaints about industrial waste from ports and fish processing decrease, raw fish and processed products are of higher quality
4.	Sea supply kiosk	Collection of solid waste from supply preparation	Sea supply area is cleaner, visitor health is more assured
5.	Provision of fuel	Collection of solid waste from the port in the fuel station area	Fuel station area is cleaner, fire risk is reduced
6.	Provision of ice for fish	Collection of solid waste in the ice factory area	Ice factory area is cleaner, ice factory performance is improved, fish cold handling is more assured
7.	Food stalls	Collection of leftover food and vegetable waste	Food stalls are cleaner, visitor health is more assured
8.	Fishery services	Coordination of fish handling and fish transportation waste	Fishery services are better and demand is increasing, cleanliness of fish transportation facilities is more assured

If the fishing port successfully handles solid waste using an incinerator, it will encourage the development of fishing activities in the Tanjung Luar FP. Many fishing boats will land their catches at the port because the dock is clean and no longer disturbed by fishing waste (Table 4). Fish auction and marketing activities can run more orderly, and the solid waste produced can be sent to the incinerator at the end of each activity. The area around the sea supply kiosk is also cleaner because packaging waste is no longer piled up for days. This then invites many fish buyers, visitors, and the community to come to the fishing port. According to Mustaruddin et al. (2022b) and Wirajing and Nanfosso (2025), fish buyers and visitors pay close attention to the cleanliness and quality of fish in transactions, because fisheries activities at the

port are a food business. These fisheries transactions will affect other transactions, such as the provision of ice, food stalls, and fisheries services. Fisheries services, for example, there will be bank transfers and fish transportation services, if there is a fish purchase. This will continue, if there is comfort in activities at the fishing port, especially in solving the problem of solid waste that is widely complained about. This study has shown that incinerators have high suitability for handling this waste, and also presents a strategy for implementing it at fishing ports. Each fisheries stakeholder can contribute according to their role in supporting the implementation of the incinerator (Table 4). This finding can be applied to all fishing ports because they have the same waste typology, and also supports the ecofishing port program initiated by the Indonesian Government (Muninggar et al., 2020; Wahyuni et al., 2022).

4. CONCLUSION

The developing fishery activities in Tanjung Luar FP were fishing boat activities, fish marketing, port industry and fish processing, provision of supplies for going to sea, provision of fuel for going to sea, provision of ice for fish, food stalls, and other fisheries services. All these activities had the potential for solid waste. The solid waste from fishery activities is net scraps, fishing line pieces, used cardboard supplies, used plastic, fallen fish, pieces of fish, fish scales and guts, fish container waste, pieces of rope, wooden crate waste, used sacks, used jerry cans, pipe pieces, used hoses, used styrofoams, used spare parts, leaves, and food waste. The suitability of the incinerator for solid waste management at the port was relatively high, which was indicated by the fulfilment of good compliance criteria (3.20 on a scale of 1-4) and very good beyond compliance criteria (3.52 on a scale of 1-4). The development of an environmental control system in incinerator operations (CONT) was priority strategy I for the application of incinerators for solid waste management in fishing ports (IR=0.245, inconsistency 0.05). The supporting strategy was the recruitment of skilled incinerator managers from the community (MANG) (IR=0.232, inconsistency 0.05).

ACKNOWLEDGEMENTS

The author would like to thank the Directorate General of Higher Education, Research, and Technology of the Ministry of Education, Culture, Research and Technology of Indonesia for funding this research in accordance with the 2024 Research Program Implementation Contract Number: 027/E5/PG.02.00.PL/2024 dated June 11, 2024. The author would also like to thank IPB University, the Department of Marine Affairs and Fisheries of East Lombok Regency, and the Bangsal Fishermen Group of East Lombok Regency for their support in data collection.

AUTHORS CONTRIBUTION

Experimental Run and Data Collection, Mustaruddin, Iin Solihin, Gondo Puspito, and Fis Purwangka; **Methodology and Validation**, Mustaruddin, Iin Solihin, and Eko Sri Wiyono; **Writing-Original Draft Preparation**, Syifa Nurul Aini, Mustaruddin, and Gondo Puspito; **Formal Analysis, Data Curation, and Visualization**, Syifa Nurul Aini and Fis Purwangka; **Writing-Review and Editing**, Eko Sri Wiyono and Gondo Puspito; **Supervision**, Mustaruddin.

DECLARATION OF COMPETING INTEREST

The authors have no conflict of interest to declare.

REFERENCES

Azeez AS, Muraleedharan KR, Revichandran C, John S, Seena G, Ravikumar CN, et al. Modelling of sediment plume associated with the capital dredging for sustainable mangrove ecosystem in the Old Mangalore Port, Karnataka, India. Regional Studies in Marine Science 2022;56:Article No. 102693.

Caramuta C, Giacomini C, Longo G, Montrone T, Poloni C, Ricco L. Integration of BPMN modeling and multi-actor AHP-aided evaluation to improve port rail operations. Transportation Research Procedia 2021;52:139-46.

Cheng Y, Oleszek S, Shiota K, Oshita K, Takaoka M. Comparison of sewage sludge mono-incinerators: Mass balance and distribution of heavy metals in step grate and fluidized bed incinerators. Waste Management 2020;105:575-85.

Department of Environment and Sanitation (DES) of East Lombok Regency. Report on Environmental and Sanitation Management and Control. Selong, Indonesia: DES of East Lombok Regency; 2024. p. 58.

Department of Marine Affairs and Fisheries (DMAF) of East Lombok Regency. Marine Affairs and Fisheries Performance Report. Selong, Indonesia: DMAF of East Lombok Regency; 2024. p. 65.

Ewell C, Hocevar J, Mitchell E, Snowden S, Jacquet J. An evaluation of Regional Fisheries Management Organization at-sea compliance monitoring and observer programs. Marine Policy 2020;115:Article No. 103842.

Firdaus M, Shafitri N, Witomo CM. Fisheries empowerment in East Lombok Regency, West Nusa Tenggara Province. Marina Scientific Bulletin 2020;6(2):85-98 (in Indonesian)

Hendrawan A. The role of incinerators in preventing marine pollution in KM. Tanto Bersama. Jogja Maritime Scientific Magazine 2022;20(1):42-50 (in Indonesian).

Ji G, Chen Q, Ding Z, Gu J, Guo M, Shi L, et al. High mortality and high PCDD/Fs exposure among residents downwind of municipal solid waste incinerators: A case study in China. Environmental Pollution 2022;294(1):Article No. 118635.

Kamargo G, Simbolon D, Mustaruddin. Capture fisheries management strategy in the Lingga Regional Marine Conservation Area (LRMCA) in Lingga Regency. Albacore Journal 2018;2(3):333-42 (in Indonesian).

Liu S, Tian F, Pan YF, Xiang LH, Lin L, Hou R, et al. Contamination and ecological risks of steroid metabolites require more attention in the environment: Evidence from the fishing ports. Science of The Total Environment 2022;807(1):Article No. 150814.

McClanahan TR, Oddenyo RM, Kosgei JK. Challenges to managing fisheries with high inter-community variability on the Kenya-Tanzania border. Current Research in Environmental Sustainability 2024;7:Article No. 100244.

McClanahan TR, Azali MK, Kosgei JK. Fish catch responses to Covid-19 disease curfews dependent on compliance, fisheries management, and environmental contexts. Marine Policy 2022;144:Article No. 105239.

Ministry of Environment and Forestry (MEF) of Indonesia. Regulation of MEF for Company Performance Rating Assessment Program (Proper) in Environmental Management: Volume 1. Jakarta, Indonesia: MEF of Indonesia; 2021.

Muninggar R, Lubis E, Iskandar BH. Assessment of ecofishingport parameters at Jakarta Nizam Zachman Oceanic Fishingport. Journal of Fisheries and Marine Technology 2020;11(1):111-23 (in Indonesian).

Mustaruddin, Baskoro MS, Santoso D, Karnan. Attractor effectiveness and squid-enrichment strategies in Tanjung Luar, East Lombok Regency, West Nusa Tenggara. Albacore Journal 2022a;6(3):281-91 (in Indonesian).

Mustaruddin, Selomita E, Nugroho T, Kartini SS. Sanitation aspects on tuna landings on Bungus Fishing Port, West Sumatra. Indonesian Journal of Agricultural Sciences 2022b;27(4):536-43 (in Indonesian).

Mustaruddin, Nurani TW, Wisudo SH, Wiyono ES, Haluan J. Quantitative Approach to Developing Fisheries Industry Operations. Bandung, Indonesia: CV. Lubuk Agung; 2011.

Osmundsen L. Port reception facilities and a regional approach: A bridge for abating plastic pollution in the arctic? Marine Policy 2023;148:Article No. 105436.

Ozkaynak OH, Icemer GT. Based on stakeholder questionnaires of ship-derived waste, waste management re-planning in Ports and determining the need for inspection. Marine Policy 2024;159:Article No. 105912.

Rosalina D, Adi W, Martasari D. Analysis of sustainable catch and squid fishing season patterns in Sungailiat Nusantara Fishingport, Bangka. Maspari Journal 2011;2(1):26-38 (in Indonesian).

Ross J, Hammouche S, Chen Y, Rockall AG. Beyond regulatory compliance: Evaluating radiology artificial intelligence applications in deployment. Clinical Radiology 2024;79(5):338-45.

Saaty TL. Decision Making for Leaders. Jakarta, Indonesia: PT. Pustaka Binaman Pressindo; 1993. p. 270.

Shofa R, Hadi H. Study of environmental sanitation of fishermen's settlements in Tanjung Luar Village, Keruak District, East Lombok Regency. Journal of Geographical Science and Education Studies 2017;1(2):22-34.

Subhan M. Analysis of handling and strategy of fish waste management at Tanjung Luar Fish Auction Place, Keruak District, East Lombok Regency. Rinjani Scientific Journal 2018;6(1):79-83 (in Indonesian).

Thanassekos S, Scheld AM. Simulating the effects of environmental and market variability on fishing industry structure. Ecological Economics 2020;174:Article No. 106687.

Vaio AD, Varriale L, Trujillo L. Management control systems in port waste management: Evidence from Italy. Utilities Policy 2019;56:127-35.

Wahyudin I, Kamal MM, Fahrudin A, Boer M. Sustainability analysis of elasmobranch fisheries in Tanjung Luar, East Lombok Regency. Journal of Tropical Marine Science and Technology 2019;11(1):103-16 (in Indonesian).

Wahyuni DM, Mustaruddin, Muninggar R. Environmental management assessment of Kutaraja Oceanic Fishingport based on eco-fishingport parameters. Albacore Journal 2022;6(2):123-37 (in Indonesian).

Wirajing MAK, Nanfosso RT. Establishing a sustainable fishing industry: The role of environmental stringency, fishery training and education infrastructure in the Maritime Cameroon. Marine Policy 2025;178:Article No. 106730.

Yang L, Liu G, Zhu Q, Zheng M. Small-scale waste incinerators in rural China: Potential risks of dioxin and polychlorinated naphthalene emissions. Emerging Contaminants 2019;5:31-4.