Current Source and Distribution Pattern of Plastic Waste Leakage in the Estuary of Jakarta Bay

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Abstract. The accumulation of plastics in marine environment has increased the global risk of water pollution. Its uncontrolled production and existing management capacity have brought a burden on current plastic waste management, especially in Jakarta Bay. It has a negative impact on land, ecosystems, and especially the food chain and marine organisms. Their improper management has reduced the quality of environment, human health, and influenced economic sectors. Economic activities which involve coastal areas have consistently become a major source of plastic waste leakage either directly or indirectly. This study aims to analyze current source and its distribution patterns of plastic waste leakage in estuaries of Jakarta Bay using in-depth interviews and field observations. The results show the estuaries at the eastern part of Jakarta Bay is the highest potential for plastic waste leakage, followed by the western part, and the middle part is the least contributing plastic waste of leakage. The various sources of leakage in the estuaries are identified, including the behavior of the community that is vulnerable to exacerbates the existence of leakage. Handling capacities are limited including facilities, and the intensity of collection in the wide coverage of the operating area made the challenges to the responsible authorities.

1. Introduction
The increasing crisis of marine plastic waste management has become a global concern given its significant negative impact on humans and the environment. As one of the contributing factors, poor management escalates the plastic pollution widely in the marine and coastal areas, threaten the economic sectors, quality of ecosystem health, coastal sanitation and aesthetics, and human health due to seafood consumption contained microplastics [1, 2]. [3] estimates that 30% of the world's 2 billion tons of solid waste is not managed properly, and the number may increase to 3.4 billion tons by 2050 if the management uses the same scenario. For plastic waste, WWF [4] predicts that in 2016 plastic waste has reached 396 MMT or 53 kg of plastic/person, and there will be an increase at an amount of 40% by 2030. Related to this number, [5] estimated that 150 million tons (MT) of plastic in the world are in the ocean and will increase by 250 MT if the trends of urbanization, production, and consumption continue. A higher number of plastic waste estimated by [6], where 275 million metric tons (MMT) were produced by 192 coastal countries in 2010, and approximately 4.8-12.7 MMT/year entered the sea, while [7] estimated that plastic flows from the global riverine system into the oceans every year at the amount of 1.15-2.41 MT.
Generally, about 80% of the world’s plastic waste estimation from land-based sources and its accumulation enters the sea and shorelines contains 60% to 90% combinations of different plastic polymers [4,8,9,10,11]. In Indonesia, the Ministry of Environment and Forestry reported that the national waste production has now reached an amount of 67.8 MT/year with 18.5% or 12.54 MT of plastic [12] (Fig 1). [5] reported that an average of 3.22 MT produced waste that was not managed properly resulted in an amount of 0.48-1.29 MMT of plastic waste leaks into the oceans/year. This range is consistent with the study conducted by [5] namely 400,000 tons/year), [13] namely 268,740 to 594,558 tons/year, or [14] namely 488,096 tons.

![Fig. 1. The composition of national waste by type [12].](image)

Plastic waste threatens marine ecosystems and environmental sustainability due to its significant volume, hazardous substance, and needs time to decompose. Microplastic including in Jakarta Bay [15] pollutes the marine food web, which later fish or other biotas (seafood) consumed by humans. Marine biota entangled by plastic material, or plastic waste contaminates coastal vegetation, soil, water, and air (waste burning) with its toxic substances and will have wider damage on marine habitats and ecosystems.

1.1. Source of Leakage and Behavior

The characteristics of semi-enclosed waters with various activities surrounding Jakarta Bay made it vulnerable to receiving dumped plastic waste from various sources, such as river outlets, households or settlements, offices, industry, fisheries, ports, and transportation. Furthermore, the Bay has become vulnerable to being a dumping ground of waste leakages from land, the sea that is carried by tides into the bay or estuaries, and the Thousand Islands.

The impact further affects directly to economic activities such as shipping, fishing, aquaculture, tourism, and recreation [2,5,16]. However, these sectors have also become the key source of marine litter, among others, including aquaculture and capture fisheries (buoys, netting, ropes), shipping (plastic pellets, ballast), transport (tire), cosmetics (microbeads), retail (plastic bags, bottles, packaging) [2,4]. Some of the used materials from fisheries activities are disposed of either intentionally or unintentionally by consumers. The proper and safe waste disposal methods tend to intentionally ignore, while the relocation of fishing gear, aquaculture, or other plastic materials by oceanographic influences (tidal, current, and wave) are disposed unintentionally. Furthermore, this condition is exacerbated by the impact of the design of single-use plastic products, the direct disposal of waste by the people living around the site and visitors [2,11], and the ineffectiveness of handling, including the availability of facilities. Consumers are playing a significant role as a source of plastic waste, directly and indirectly. They contribute to a large proportion of marine debris, such as the uncontrolled disposal of packaging or plastic bags into the environment, including single-use plastic products. The consumers contribute in different contexts, such as visitors or people who live in that areas, work, and littering in daily activities [2].
Considering the impact on the coastal environment and human health, so far there have been many programs or interventions conducted without a guarantee of effectively reducing or solving problems. The initiatives other than technical solutions as [17], a perspective on human behavior impact and plastic consumption behavior is needed as strategic intervention through learning habits, norms, and situational factors although long-term effects are often uncertain. Similar to [18] on handling plastic pollution, the human dimension approach plays an important role in coastal and marine areas. This approach can explain their role in the plastic cycle, starting from the production-consumption-waste processing, and human decisions or behaviors on waste to end up in the coastal and marine environment. The approach is also important as a reference in the process of planning and implementing social change programs.

1.2. The Government Action Plan
The government has declared the target of marine debris reduction by 70% through the 2018 - 2025 action plan based on Presidential Decree 83/2018 concerning Marine Debris Management [19]. On the other hand, the National Policy and Strategy (Jakstranas) for the Management of Household Waste and Similar Types of Household Waste (Presidential Decree 97/2017) also targets a 30% reduction and 70% waste handling through the 2018 – 2025 action plan [20]. These policies derivative is followed up by the DKI Jakarta Government Regulation 108/2018 at the Regional Policy and Strategy (Jakstrada) level. Regulatory effectiveness plays an important role in dealing with the complexity of current management. Therefore, it is necessary to review performance including gaps in the implementation of policies, action plans, existing instruments, and to anticipate the need for policy and scenario options. This process is important to ensure the target can be achieved optimally and effectively.

The study aims to analyze and review the current source of leakage and its distribution patterns of plastic waste leakage in the estuaries of Jakarta Bay with focusing on the identification and description of the potential area of plastic waste leakage, the pattern of accumulation, distribution, and leakage handling, community behavior and coordination mechanism.

2. Methodology
2.1. Study Site
The study site of the research was conducted in Jakarta Bay, DKI Jakarta Province, and was divided into 3 zones namely eastern, middle and western, with 2 category of sampling areas namely river outlet and port zone (Fig 2). There were 13 stations of study site which 2 stations in the western zone located in Banten Province namely Cisadane and Dadap, while the other 2 stations in the eastern zone located in Jawa Barat province namely Citarum and Kali Bekasi or Cikarang Bekasi Laut (CBL). The other stations were located in DKI Jakarta Province and were selected based on the potential of various sources of plastic waste leakage such as river outlets, public ports and fisheries, households and fishing settlements, and other places like offices, markets including fish landing sites, fishing docks, and other relevant sites. The selected coordinates of the plot per station are Cisadane (-6°0’11″, 106°33′46″), Dadap (-6°5’32”, 106°42’31″), Cengkareng Drain (-6°6’14″, 106°45’4″), Banjir Kanal Barat/Kali Adem (-6°6’41″, 106°46’11″), Kali Adem Port (-6°6’15″, 106°46’18″), Muara Angke Fishing Port (-6°6’13″, 106°46’34″), Nizam Zachman (-6°5’56″, 106°48’2″), Sunda Kelapa (-6°7’27″, 106°48’33″), Marina Ancol (-6°7’16″, 106°49’45″), Tanjung Priok (-6°6’16″, 106°53’26″), Banjir Kanal Timur (-6°5’28″, 106°58’11″), Cakung Drain (-6°6’5″, 106°56’25″), Kali Bekasi/CBL (-6°3’10″, 106°58’44″), Sunter (-6°6’25″, 106°54’25″), and Citarum (-5°56’27″, 106°59’26″).

2.2. Data Collection
Data collection was using a combined methodology of field observation and in-depth interview. Field observation was conducted in 13 stations, with 4, 5, and 6 stations for each western, eastern, and middle zone respectively. A sampling of plastic waste was conducted at 3 plots of 3 x 3 m²/stations.
through collecting, put in a plastic bag, labeled, and weighed. Field observation was also conducted to identify and recognize various types of events, happenings, situations, actions that formed patterns from day to day within the observed site and communities. In-depth interviews with semi-structured form were conducted in 12 stations with 100 interviewees, 8-9 persons per station, with the various background of ages, education, gender, and professions such as fishers, boat owners and crew, port managers and workers, housewives, visitors, shop owners, fish and market traders, employees, recyclers and waste collectors (Table 1). Study literature was also conducted as a source of secondary data such as relevant research, documents, and reports.

Fig. 2. Study site of the research in Jakarta Bay estuaries.

2.3. Data Analysis
The amount of plastic waste was collected and weighed to obtain the type, amount, and weight of the sample at each plot and station. Other data from field observation such as pattern, behavior, trend, specific situation, or action was categorized using qualitative method through data reduction, unit sorting, categorizing, and grouping into thematic issues. Data from an in-depth interview was categorized as a social indicator namely knowledge, perception, participation, and behavior. The answers of each category were calculated and divided into 2 types namely Good and Less. The percentage of these types was calculated to obtain the average number.

3. Result and Discussion

3.1. Source of Plastic Waste Leakage
Jakarta Bay has the potential as the endpoint of various sources of plastic waste leakage, such as the outlets of river systems, port areas including anchored ships, settlements, and fishing households, the waste from outside estuaries such as the Thousand Islands water, and from passing marine transportation.
Table 1. The characteristic of plastic waste leakage in the eastern part of Jakarta Bay estuaries.

| Source and Type | Amount (item/m²) | Weight (g/m²) |
|-----------------|------------------|---------------|
| Cakung Drain/Cilincing Fisher’s Village: Household, fishing activities, fish market, river material, boats-crew material, shops, overloaded trash cans, docking. Mainly plastic packaging, bottles, utensils | 721 | 6597 |
| Sunter (waste net): Household, boats-crew material, shops, docking. Mainly plastic packaging, bottles, utensils, bag | 510 | 4471 |
| Banjir Kanal Timur (BKT) (sluice gate): Households, fishing activities, boats-crew material, shops, docking, visitor. Mainly plastic packaging, styrofoam, utensils, bag | 1321 | 10511 |
| Kali Bekasi (SeeHamster boats): River materials, households, shops, offices, passers. Mainly plastic packaging, bag | 546 | 7610 |
| Citarum: River materials, households, shops, boats-crew material, passers. Mainly styrofoam, bottles | 305 | 6047 |
| Total of Eastern Part | 3403 | 35236 |

Leakage Pattern: Mostly dumped into the riverbank, floats, settles in the bottom, trapped in the riverside, between anchored ships, dock and mangroves. Some is carried away by tides to the estuaries and vice versa.

Table 1 shows that all outlets in the eastern bay area are active as sources of leakage and contribute significantly to the accumulation of plastic waste in Jakarta Bay. At each outlet, the waste dumped into riverbanks, accumulated in some points, some scattered and not collected properly. The dumped waste spreads in various ways, such as accumulated on the riverbanks, settles in the bottom, trapped between ships, docks, or port’s pool, some floating and carried away by tides from estuaries. The time of wet seasons to occur is mainly on December-February will influence their spreads pattern and may increase the waste transported from terrestrial [21] or open seas. In a particular case like Kali Sunter and BKT, the floating waste that concentrated in the deeper sea is carried by tides into the estuaries.

The source of leakage in the eastern bay derived from several activities such as river flow, related fisheries (fisher's households, fish markets, loading and unloading fishing boats, material from crews and repairing boats), shops, overloaded trash cans, visitors including waste from outside the area. The majority of the discarded waste was dominated by plastic material (containers/bags) and single-use, including waste from fishing gears such as nets, ropes, floating balls, and others. Cilincing Fisher's Village is one of the vulnerable to leakage. A significant plastic waste is produced every day in Cilincing Fisher's Village due to various activities conducted at the same places and mainly from fisher’s households, fishing activities, and shops. The outlet of Kali Sunter and BKT is being more manageable due to either the existence of sluice gates or waste nets or private waste vessels prepared by a certain company (Pertamina, PT Boga Sari) operated in the Kali Sunter outlet area. However, an amount of significant accumulation still produces plastic waste in the area beyond this instrument because the existence of some activities and smaller size of waste still escape pass through the gate to the sea. Table 1 shows BKT is the highest amount and weight of plastic waste collected from sampling area in the eastern part, while the lowest is Kali Sunter. In particular, a significant amount of waste from outside estuaries and riverbanks of BKT accumulated in one side of the outlet and formed a vast additional land of waste. Since the waste production still occurred at all sources and the area beyond the sluice gates is relatively less controlled, it needs to ensure the existing instrument is working properly and to increase the intensity of collection. Although the collecting and controlling efforts are in place, inadequate capacity (equipment, personnel) and intensity of waste collection still need improvement. Relevant work units and authorities need to increase the intensity of waste collection and control in areas like this.

The other vulnerable was the Kali Bekasi outlet due to the existence of many activities in the midstream before estuaries such as households, shops, market, and offices. Kali Bekasi discarded plastic waste at amount of 31% (2.61 ± 1.31 tons/day) [22], while BKT outlet is 0.7 tons/day [23]. However, a different result at Table 2 shows the amount and weight of plastic waste of BKT is higher
than Kali Bekasi. A recent improvement from Kali Bekasi is the deployment of a new fleet of waste vessels but not operated in river outlets. Most of the outlets at eastern bay have a limited number and capacity of trash cans which are vulnerable for the plastic waste not being managed properly, and inadequate existing waste collection facilities. In addition, the pattern of waste collection that tends to be less intensive exacerbates the accumulation of waste. It needs more effort from authorities in the estuaries with no sluice gates or waste nets, and riverbanks that are using as residential locations or related fishing activities.

### Table 2. The characteristic of plastic waste leakage in the middle part of Jakarta Bay estuaries.

| Source and Type | Amount (item/m²) | Weight (g/m²) |
|----------------|-----------------|---------------|
| Tanjung Priok Port: Outside port, boat-crew materials, visitors. Mainly utensils and plastic packaging | 45 | 84 |
| Nizam Zahman Fishing Port: Boat-crew materials, visitor, from outside port, docking, overloaded of trash cans. Mainly utensils, bottles | 119 | 1691 |
| Sunda Kelapa Port: Boat-crew materials, visitor, carried from outside port area, docking, overloaded of trash cans. Mainly utensils and bottles | 432 | 2782 |
| Ancol Dock: Boat-crew materials, visitor, from outside port, docking, overloaded of trash cans. Mainly plastic packaging and utensils | 146 | 865 |
| Kali Adem Port: Households, shops, boat-crew material, visitors, from outside port incl. Angke fisher's settlements. Mainly plastic packaging and utensils | 227 | 1851 |
| Muara Angke Fishing Port: Households, water flow connected to port, fishing activities, shops, boat-crew materials, docking, visitors. Mainly plastic packaging, bottles | 514 | 7235 |
| Total of Middle Part | 1483 | 14508 |

**Leakage Pattern:** Some port mostly from outside port, other dumped in port waters, trapped in pool-under-corner of port, in between boats, floats, settles in the bottom. Some carried by tides into the port water and vice versa.

Meanwhile, the majority of the area in the middle bay is occupied by public and fishing ports or offices, and relatively encountered the influence of river outlets indirectly, for example, floating waste in the deeper sea possibly enters the port or estuaries by tides influences. The main source of the leakage is produced by the shops, visitors, households, and the waste that is carried by the tides from outside the port water. Others come from the material from fishing or logistic boats that were anchored in the pool of port. Plastic waste that is found in the port waters, scattered and floating at the corner of the port pool, between the boats and docks. Most vulnerable of the leakage is coming from either inside (activities within a port area) or outside the port area by the tide’s influence. Port authorities mostly suffer from both, where its mixing enables a significant amount of plastic accumulation, as [21] particularly occurred during wet seasons. Tanjung Priok authority reported that overall waste from both land and seas is about 79.4 tons/day, where 18-24% consist of marine debris including plastic. Specifically, this area is the lowest source amount of plastic waste compared to others in the middle part of the bay (Table 2). A hired company equipped with a waste vessels fleet is responsible for waste collection at Tanjung Priok port waters. However, the area is relatively close to three river mouths namely Kali Sunter, Kali Jabat, and Kali Lagoa and they suffered from plastic waste that comes from these river mouths. Another potential of a significant source is also coming from some area of water beyond the coastal water, as reported by [24]. Approximately about 31.66% of marine debris particles are originating from the South China Sea, 68.18% from the Indonesian seas (north of Java, the southern part of the eastern coast Sumatera, and the west coast Kalimantan), and the rest from the western tropical Pacific and the Indian Ocean.

The leakage in the middle part of the bay is relatively lower than the eastern and western parts, although sometimes port authorities encountered challenges to deal with both sources. Besides being more manageable, indirectly impact from the river outlets, limited access in a certain area, it is also due to the better waste management protocol that some ports have compared to the other two parts of...
the bay, including the availability of waste collection equipment owned by each port (Pelindo, Nizam Zachman Fishing Port). In particular, some ports also struggle to handle plastic waste as they exercise poor waste management, for example, Muara Angke Fishing Port. As shown at Table 2, this port is the highest amount of plastic waste in the middle part. Kali Adem port also consistently receives waste from other ports that existed very close to their port, for example, a small dock for fishing boats side by side with fisher’s house (Muara Angke Docks). The middle part of the bay also has the potential to produce a significant accumulation of plastic waste. Some of the certain areas are close to the fishing households and small fishing docks with poor waste management, a thousand fishing and logistic boats in-out every day, the existence of some shops in certain ports, and the behavior either by visitors or passers. Therefore, as suggested by [21], it is necessary to anticipate the significant contribution of plastic waste leakage from this part of the bay to Jakarta Bay.

### Table 3. The characteristic of plastic waste leakage in the western part of Jakarta Bay estuaries.

| Source and Type                                      | Amount (item/m²) | Weight (g/m²) |
|-----------------------------------------------------|------------------|---------------|
| Cisadane: Household, factories, boat material, shops, passer, river material. Mainly plastic packaging and bag | 338              | 4614          |
| Dadap: Market, household, boat material, river material, shops, passer, river material. Mainly styrofoam, bottles and plastic bag | 744              | 13431         |
| Cengkareng Drain (sluice gate, interceptor): Household, boat material, shops, docking, small size of plastic escape from vessel’s filter. Mainly plastic bag and packaging, utensils | 72              | 758           |
| Banjir Kanal Barat/Kali Adem: Household, river material, shops, docking, boat-crew material. Mainly plastic bag and packaging, bottles, styrofoam | 1168            | 10891         |
| Total of Western Part                               | 2322             | 29694         |

**Leakage Pattern:** Mostly dumped to river, trapped in the riverside, between ships-bridge-docks-house, settles in the bottom, mangroves, and carried by tide into estuaries and vice versa

The plastic waste leakage in Jakarta Bay from the river outlets that are administratively outside DKI Jakarta, such as the Cisadane and Dadap (Table 4), Kali Bekasi and Citarum (Table 1) tend to have less control by the DKI Jakarta authorities as to the affected area. The authority of Banten and West Java Provinces are focusing on both upstream and midstream, while the estuaries are less monitored and control by the DKI Jakarta authority. Dadap River (Tangerang) is a center of public activities along the riverbanks that are occupied by the potential source of leakage. These are households-market-shops. The riverbanks in some points are used as trash cans. Another source is coming from the passers, material from ships that are often docked in the estuary, and material carried by river flow.

These sources of leakage are consistently producing a significant amount of plastic waste every day and accumulate in some points of distribution along the river. A large amount of waste is accumulated in the middle of the river and it has been also used as a collection point. Some waste is dumped directly into the river, scattered on banks, and fell into the river. Others are collected by the waste collector, while the majority will gradually be carried into the sea at low tide. Some of the waste is picked up by the local authorities, while others have not been successfully removed, even they have repeatedly increased in volume from these sources. Dadap River is one of the main rivers with significant plastic waste leakage with an amount of 2.15 ± 0.88 tons/day or 26% [21,22], while Banjir Kanal Barat/Kali Adem was discharged at an amount of 1.5 tons’ plastic/day [23]. Similar to Table 3, the Dadap River outlet is the highest amount of plastic waste in the western part of the bay, and then followed by Kali Adem. In the case of Kali Adem, one side of the riverbank is occupied by a fisher’s house, fishing docks, and shops. The main source of the leakage is coming from households where all the waste is dumped and collected at riverbanks without trash cans, only a few collected waste properly. Another significant source of waste is the material carried by the river from the upper stream, boat and crew materials, and docking. Cengkareng drain is the lowest as Table 3, even though
also discharged plastic debris at an amount of 0.5 tons/day [23]. Based on [21,22,23], both are among the contributing rivers to an estimated 57.668 ± 16.559 plastic items/day leakage to Jakarta Bay.

Based on other related research [25,26] in [21], big rivers like Cisadane and Citarum are among the main river consistently flowing the plastic waste into Jakarta Bay with 40-120 m³/s and 3-370 m³/s respectively. As observed, it is predicted that the large volume of plastic waste from the Cisadane River each day ended up in the beach area of Cisadane’s estuary, forming a long ‘a plastic beach’. The main source of the leakage is the households, shops, factories lied along with the riverbank and the river materials from the upper stream. Other sources from passers and plastic material that are carried by tides into estuaries.

![Fig. 3. The comparison of plastic waste in the western, middle and eastern part of Jakarta Bay.](image)

As shown in Fig 3, the highest of plastic waste is found in the eastern part and the lowest in the middle part. Majority of identified plastic material consistent with [21,22,27] such as containers, packaging or personal product (utensil, detergent, food product, bag, toy, cosmetic), single-use (sachets, bottles, cups, glasses, straws, styrofoam), and household’s tools. Those wastes are known as macroplastic and identified as common materials exported by the rivers to the sea [28]. Their source of leakage in estuaries is through the river flows (waste flow from upper stream), related activities at riverbanks, ports, and waste that is carried from outside estuaries. In the rivers or estuaries, the waste is collected in sluice gates or waste nets, or collected by vessels. Other is tend to be uncontrolled, scattered, and accumulated in some points, settle in the bottom, trapped in some places, floats, and flow to the estuaries. The potential of a significant amount of waste is possibly found in the area of river outlets, settlements including fishers’ households, and fishing ports that occupied the same banks and estuaries. It is even worse for the river outlets outside DKI Jakarta with relatively less control. The temporary status of fishing households creates another problem. They are vulnerable being less responsible for environmental cleanliness as they thought will not stay permanently. As a result, more significant plastic material will be produced and escape into the estuaries and coastal waters. The eastern and western parts of Jakarta Bay is representing of this case.

### 3.2. Community Behavior

Table 4 shows that the level of knowledge of the respondents is quite good related to the impact of plastic waste on health and the environment, and the prohibitions/sanctions are 72.5% and 80%, respectively. However, a lower percentage is about 12.5% on reduction and handling of plastic waste. Respondents have sufficient knowledge on those categories, but at the same time, they do have insufficient knowledge about ways to reduce and handle plastic waste such as limiting the use of plastic bags, single-use or plastic recycling.
Tab. 4. The knowledge, perception, and participation on plastic waste leakage.

| Knowledge                        | Number of respondents | Percentage (%) |
|----------------------------------|-----------------------|----------------|
| Impact on health and environment | 100                   | 72.5  27.5     |
| Prohibitions and sanctions       | 80                    | 20             |
| Methods of reduction and handling| 12.5                  | 87.5           |
| **Perception**                   |                       |                |
| Availability of facilities and infrastructure | 56.25 | 43.75 |
| Role of Village-related work units | 68.75 | 31.25 |
| Enforcement (prohibitions, control, sanctions) | 55 | 45 |
| Role of other stakeholders       | 12.5                  | 87.5           |
| Benefits of socialization/technical guidance | 25 | 75 |
| **Participation**                |                       |                |
| Socialization/technical guidance | 18.75 | 81.25 |
| Working with other community (gotong royong) | 10 | 90 |
| Working with local authority/other stakeholders | 10 | 90 |
| Plastic bags reduction           | 6.25                  | 93.75          |
| Single use plastic reduction     | 7.5                   | 92.5           |
| Recycling plastic                | 10                    | 90             |
| Sorting from home                | 10                    | 90             |

Respondents' perceptions on the availability of supporting facilities and infrastructure were relatively balanced, where 56.25% said it was sufficient and 43.75% thought it was not enough. Some areas at the ports and estuaries have been accessed by ships or waste boats, but the intensity of collection and the ship capacity are insufficient. Some locations with high leakage rates still show accumulated and scattered waste even though they have been cleaned. In the estuary area, ships tend to clean only the area that easy to access such as the middle of the river and pool of port, but the Riverside area, the corner of the port pool, and the area between ships or docks are not reached. The intensity of collection is also relatively less, on average only once every 2-4 days. As a result, the accumulation and distribution of waste are unavoidable. The condition of the availability of facilities and infrastructure in each location is also not the same. In some locations like Cilincing Fisherman's Village where the leakage rate is quite high, the number of trash cans especially in riverside and related fishing activity areas is still limited. The majority of existing trash cans are small and most of the time is overloaded then it is scattered and fall into the river/sea. In the case of Kali Adem and Cakung Drain riverbanks, fishers are directly throwing waste at the banks and using it as a temporary trash can for collecting waste which also functions as the backside of their house.

On the other hand, a fleet of orange vessels deployed by local authorities in the bay waters, deep sea, and the Thousand Islands waters to collect floating plastic waste. The average amount collected from the sea reaches 5 - 7 tons/day or 60-70% of the optimal fleet capacity, considering the wide coverage area of operation. This collected plastic waste is in the range of numbers reported by [22] at an amount of 2.44-8.32 tons/day in estuaries or coastal waters. A higher recent estimation using combined data between [22] and Dinas Lingkungan Hidup DKI Jakarta 2021 at an amount of 2.82-8.7 tons/day.

A balanced percentage perception of the availability of facilities and infrastructure (Table 4) indicates that the presence of existing waste facilities can be useful, but the leakage of plastic waste continues in several locations. The condition of this leakage by some respondents was considered as a result of the lack of trash can and less collection intensity. In this case, although the local government and its subordinates have made efforts, as indicated by the perception of respondents 68.75%, the actual conditions show that the availability of waste facilities is not sufficient to control the leakage of plastic waste in Jakarta Bay.

Respondent’s perception on the existing rule enforcement such as prohibitions, monitoring, controlling and sanctions had been carried out properly or not is sufficiently balanced at the amount of
55% and 45%, respectively. In several locations such as Kali Sunter and PPS Nizam Zachman, the authority (unit work of village or RT-RW) actively monitors and reprimands residents who do not comply, even port managers do not serve the ship licensing process if they are proven not to comply with the rules. On the other locations such as Kali Adem outlet, Cilincing Fisherman’s Village, and Muara Angke Fishing Port, respondents have not seen such enforcement conducted optimally or at all. In all locations, respondents’ perceptions of the involvement or role of other stakeholders and the benefits of socialization/technical guidance are still below 30%.

Respondents assessed that community participation in efforts to handle plastic waste leakage into the sea was still low below 20% (Table 4). The indicators of participation include the socialization of activities or technical guidance, collaboration with other community members, working with local authority/other stakeholders, and involvement in plastic reduction and waste management. Low participation due to several things such as the socialization program has not been intensive and massive, the lack of public dedication, high dependence on the local authority in managing waste, the implementation of the circular economy is not yet optimal, and unwillingness to engage. Residents living in temporary settlements such as those on the banks of some river outlets like Cakung Drain, Kali Adem, and Dadap tend to have relatively lower dedication and responsibility compared to permanent ones. Table 5 shows the behavior and attitudes on ‘after the use of plastic’ and ‘seeing the accumulation of plastic waste in the sea and its surroundings. Although the percentage of those who comply with ‘disposing of in the trash can’ is quite high (92.5%), the number of ‘dumping/collecting to the river bank/sea’ is still relatively high (66.25%), while the ‘sorting waste from home’ is below 5% (Table 8a).

Table 5. The behavior on the leakage of plastic waste into the estuaries.

| (a) After the use of plastic | Number of respondents | Percentage (%) |
|-----------------------------|-----------------------|----------------|
| Disposing of in the trash can | 100                   | 92.5           |
| Dumping/collecting at the river bank/sea | 66.25 | |
| Sorting waste from home | 3.75                   |                |

(b) Seeing the accumulation of plastic waste in the sea and its surroundings

| Other people/RT-RW/waste man will take care of it | 100 | 93.75 |
| Will disappear by itself / carried by the current to the sea | 77.5 | |
| Mixing plastic waste with watery land (compaction) | 2.5 |
| More focus on livelihood | 48.75 | |
| It's common practice and not disturbed | 73.75 | |
| Reporting to the waste man / RT-RW | 18.75 | |
| Prevent/invite for cleaning together | 22.5 | |

The behavior of respondents on the one side is obedient in disposing of plastic waste at trash cans (TPS), but in some locations the number and capacity of TPS are limited, the intensity of collection is low, or the production of waste is high so that waste is scattered, which is also the reason why residents look for alternative trash cans, including collected at the riverbanks. Table 5a shows that 66.25% of respondents are still dumping or collecting at the river bank/sea, although in some places there are no trash cans found. This condition can affect the behavior of residents and spread widely in certain locations so that it has the potential to form a habit or culture. This is shown in Table 5b, where 93.75% chosen to not be responsible for the waste that is scattered or accumulated on the banks of rivers or sea but other people, waste man, or RT-RW will take care of it. For the attitudes related to habits or culture, 77.5% said plastic waste will disappear by itself or be carried away by tides to the sea, 73.75% said that it’s common practice and not disturbed, and 48.75% prefers to focus on livelihood. Meanwhile, the percentage on ‘reporting to the waste man/RT-RW’ and ‘prevent/invite for cleaning together’ is relatively small at below 25%. Some of the attitudes show lower concern, initiative, dedication, and responsibility of the community. It is suggested by [29] to improve the capacity of individuals to the level of high environmental self-efficacy and to engage more in pro-
environmental behavior. This underlines the importance of behavior and also as a challenge for the local government even though in some locations the village cadres have been assigned to support RT-RW. Other approaches as [30], The National Movement for Improving Behavioral Change as one of the main pillars of the National Action Plan on Marine Plastic Debris can be used for cross-sector stakeholder engagement to effectively improve this issue. It is proposed by [31], to avoid the generation of marine litter, awareness-raising can be focused on an improvement of habits and social norms to support the behavior change intervention.

3.3. Leakage Handling Pattern and Coordination Mechanism
In estuaries like coastal environments and shallow waters, the pattern of preventing plastic waste leakage into the sea relies on the performance of the kelurahan or village task force through the outreach programs, surveillance and routine collection, provision of facilities and infrastructure, and community participation. However, the average percentage of perceptions concerning facilities, work unit performance, and enforcement is still 60% (Table 6), while the level of community participation is very low (Table 7).

The pattern of handling plastic waste in Jakarta Bay by the DKI Jakarta government and its Environmental Service Office is carried out by dividing the handling zones based on cities and islands. For estuary areas including shallow and coastal waters, officers are equipped with garbage collection facilities including small boats, while for bay waters and beyond to the deep sea and the Thousand Islands, they are equipped with a fleet of orange boats to collect floating plastic waste. Every day the collected waste is brought to Bantar Gebang (TPA). Plastic waste collection is also carried out by port authorities, for example, Nizam Zachman Fishing Port, and some companies like Pertamina and Pelindo mostly in their surrounding waters, using their equipment including waste vessels. Meanwhile, plastic waste that leaks into the river is collected at control points such as sluice gates or waste nets. However, not all rivers are equipped with control instruments so that the potential for plastic waste to escape to the estuaries remains high, including those rivers outside the DKI Jakarta Province such as the outlets of Citarum, Bekasi, Cisadane, and Dadap.

Plastic waste originating from various sources on land enters the sea and due to oceanographic factors is concentrated in the waters of Jakarta Bay. At high tide, the plastic waste is carried into the estuaries [13,27] and trapped in several places such as under the port or anchor pool, between ships, corners of the port, and even stuck in the mangroves.

As the conditions of this pattern of leakage and waste handling, it is predicted that plastic waste produced in the area of Jakarta Bay is faster than existing control measures such as the routine operation of collection, reduction of plastic bags, packaging, or single-use plastic, innovation of recyclable plastic or any other circular economy means, and even public awareness which needs evolution to change the behavior. Social, economic, and cultural backgrounds also shape the community behavior which affects the level of leakage and the effectiveness of prevention and handling, including law enforcement. In addition, the Jakstrada action plan, which has been the target of handling and managing household waste for 2018-2025 in DKI Jakarta, has so far not been implemented optimally and effectively.

Some recommendations as a follow-up from responsible authority for further consideration are to include i) the evaluation of the use of space, especially in the estuaries and riverbank areas that are residential locations, ii) to increase the handling capacity and intensity of collection within the DKI Jakarta Provincial government and its subordinates, iii) strengthening rule enforcement through surveillance and imposition of sanctions, iv) increasing public awareness and participation, and v) establishing a task force for handling inter-provincial plastic waste leakage.

4. Conclusion
The estuaries in the eastern part of Jakarta Bay is the highest potential for plastic waste leakage, followed by the western part, and the middle part is the least contributing plastic waste of leakage. This indicates the different characteristics of the source and load of leakage.
The existence of the various source of leakage in estuaries is actively exercising the leakage such as river mouth materials, the use of riverbanks by households, offices, markets, shops, and related fisheries activities. The leakage has also occurred at public ports and other sources like visitors and passers. Other sources are from outside the estuaries such as marine transportation and marine debris that is carried by the tides into the bay waters and estuaries.

In general, the leakage pattern to the estuaries is disposing of waste either directly or indirectly. Some of the waste is disposed directly to the river, port waters, or seas, while others are indirectly disposed to the riverbanks or other areas as temporary trash cans. This waste then accumulated, scattered from overloaded trash cans, and fall into the estuaries or port waters either intentionally or unintentionally. The waste in estuaries or port waters spreads in some ways such as stuck in the riverbank, settles in the bottom, spreads and floats, trapped between ships, docks, in the pool of anchored. The pattern of spreading is influenced by river flow, tides, and the intensity of collection.

Social indicators such as knowledge, behavior, perceptions, and community participation in estuaries have not fully supported the efforts on preventing and handling the leakage. The behavior influences the existing efforts and is vulnerable to exacerbating the leakage. This behavior is a challenge and tends to be contagious and creates an unsupportive habit that leads to an unwillingness to engage. Furthermore, the prevention and handling efforts conducted by local authorities and their subordinates have not been optimal in the reduction of plastic waste leakage in estuaries. This is due to the limited number of facilities, the intensity of collection, the wide coverage of the operating area, and the ongoing level of leaks.

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