Tracking the Stranded Area of Marine Debris in Indonesian coasts by using Floating Drifter

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Abstract. Plastic litter had become world major concerned since 2015 and Indonesia had been placed as the second contributor after China. Around 200,000 metric tons of plastic wastes discharged from Indonesia rivers mainly from Java and Sumatra Islands every year. This surge of waste then become a serious threat to ocean and coastal ecosystem, as well as marine biota conservation in Indonesia. Therefore, it is very important to study the seasonal pattern of marine debris and monitor the dispersion within Indonesian water in near real time. By year 2020, an initiative action has been taken by The Ministry of Marine Affairs and Fisheries of Indonesia. More than 20 drifters were released on 3 selected rivers’ mouth in Indonesia namely Cisadane, Bengawan Solo and Musi. Results indicated that marine debris are drifted away, influenced by wind and current from time to time. The simulation will forecast the time and location where the marine debris expected to traverse and stranded in each season. This information will be very important to provide the baseline information of marine debris movement, locally and even beyond of Indonesian. Also, it will improve the mitigation, better coordinative action plan and encouraging further marine debris research in Indonesia.

Keywords: Marine Debris, Tracking, Drifter, Indonesia
1. Introduction

The Indonesian archipelago occupies a unique position on the globe both in terms of the ocean processes (The Indonesian throughflow water properties modification) that exits there and its unique marine fauna and flora [1]. As a nation resolutely turned towards the sea, Indonesia largest population centers are all coastal. As a result, the issue of plastics whole often turns into a marine plastic issue. Indeed, Indonesia is estimated to be the second largest emitter of riverine plastic [2], most of which end up in the sea [3]. Recent studies suggest that the primary control on plastic emission into the sea via river is river discharge [4]. For the island of Java, this means that peak emissions usually occurred in February [5].

Accumulation of marine plastic litter in the environment have adversely effects on wildlife, its habitat, and humans. About three quarters of all marine debris are plastic. Many marine animals have died from entangled and drowned by plastic debris or ingesting microplastic particles that cannot be digested. Toxins leach from plastic as it breaks down, posing health risks for animals, also entering the food chain, and ending up in human life. Most of marine debris is believed originated from unmanaged land-based waste, while establishing a good waste management is a major challenge for coastal countries. As a result, there are four rivers in Indonesia’s that classed as the top 20 most polluted river in the world due to mismanaged plastic waste (measured in metric tons) [2]. This makes Indonesia the second-largest contributor to marine plastic pollution after China, where approximately 200,000 tons of plastic per year are entering the ocean from rivers and streams, mainly from Java and Sumatra Island.

In that context, the Government of Indonesia through the Ministry of Marine Affairs and Fisheries (MMAF) have collaborated with the World Bank and CLS to conduct research on the monitoring of impact and accumulation of marine debris in Indonesian waters. This study aims to improve the understanding of marine debris movement and its distribution on the ocean, including in shallow waters. This study will provide a spatial and statistical view of the marine debris hotspot at sea coming from several most polluted rivers in Java, to the Government of Indonesia (in this case, is the MMAF). Hence, the Government of Indonesia can share knowledge perspective with experts, local governments, communities, and other stakeholders, which lead to a better coordinative action plans between central and local governments in combatting marine debris, also can designing more effective public campaign and clean-up action plan. This spatial and statistical result should also be built aligned with the existing surveillance equipment at MMAF.

2. Material and methods

Monitoring and simulation of marine debris movement in this study is conducted using a platform which combines data acquired from Argos based drifters and CLS modelling tool, called Mobidrift.

2.1. Monitoring

As detailed in the Guidance on Monitoring of Marine Litter in European Seas, the principal tool for monitoring litter at sea is through visual observation. Detailed protocols have been set up to standardize data collection for European Seas but there is no global standard observation protocol which makes inter comparison of data difficult [6]. A recent white paper [7] proposes a unified approach via an integrated marine debris observing system (IMDOS). There is a sustained effort to rely on voluntary observations by non-professional to track the presence of litter [8], including in coastal areas. Although this can be highly effective, the sharing of the data with the wider scientific community remains an issue [6]. Other methods are also used such as stomach content analysis, aerial surveys which are suited for plastics of sizes 30cm and above, net tows and image analysis. The Monitoring of Marine Plastic via satellite is an ongoing area of research but has yet to yield conclusive results. Current efforts are focused on the analysis of the electro-magnetic spectrum [9] and the most promising route appears to be that of shoreline (dry) detection. For the water only environment, the signal to noise ratio is high and complicates the identification of marine plastic.
2.2. Modelling

Nowadays, the best suited tools to understand the circulation dynamics in a given area are numerical models and these are routinely used in search and rescue situation and oil leakage events. They are often used as inputs to Lagrangian drift models [10][11][12] to tackle the issue of plastic pollution at sea. Compared to search and rescue and oil spill, the issue of marine plastics has the added complexity that the sources are numerous [13][14] and not well known. Furthermore, the diversity of Marine plastic mean that their drift behavior can vary significantly not only between types but also overtime as their buoyancy changes [15], and it is challenging to get a holistic view.

2.3. Drifter specification

Several satellite-based drifters are used to generate near real time data of marine litter movements at sea (Figure 1). The movement of these drifters can be monitored without any coverage limitation, or communication disruption caused by harsh environment conditions. Drifters used for this project are MAR-GE/T which use Argos satellites as their main communication link. The MAR-GE/T for this project is specifically designed to drift. It is particularly adapted to the need of such program. Robust and very easy to deploy, the device offers a long autonomy and simple commissioning colorized. This drifter is equipped with four lithium battery set to 7.2 volts and 26 Ah. Tracking data are recorded in hourly sequence, where they will be transmitted with the last 3 hours positions every 180 seconds. With this arrangement, drifters are estimated to transmit their positions for at most 12 months. By using these drifters, near real time data of marine litter movements at sea can be acquired, while the movement of drifters can be monitored without any coverage limitation, or communication disruption caused by harsh environment conditions.

2.4. Mobidrift Client Portal

The Mobidrift Client (MDC) portal is a web-based application developed by CLS as part of the marine debris monitoring program. Mobidrift is an oceanographic modelling module to simulate drifting object on the oceans under the influence of winds and currents. The MDC portal allows users to create drifting simulation, monitor drifters which have been deployed in different locations, and analyze their movement. This portal should also be able to display and visualize drifter simulations, Argos drifters’ data, and METOC data, since it is connected to three application servers (Figure 1(b)):

1. Mobidrift System, generate drifting simulation based on parameters given by the MDC,
2. Argos-System portal, provides Argos locations coming from drifters,
3. METOC server, provides METOC forecast data.

2.5. Deployment process

Drifters have been deployed at the mouth of major rivers which traversing high populated cities, where these rivers are assumed as carrier of unmanaged land-based waste into the ocean. For this initial research, three major rivers are investigated (Figure 2), i.e.:
- Cisadane river on Java Island, where traversing high populated cities in West Java and Banten Province. Cisadane is one of the five rivers containing the most plastic litter in Indonesia.
- Musi river on Sumatra Island, where traversing the Palembang city. The large delta of Musi river mouth is known as a high spot of plastic pollution.
- Bengawan Solo on Java Island. It is the longest river of Java, crossing several high populated cities in Central and East Java Province.

In 2020, twenty drifters have been deployed. Some stranded drifters were sent back to CLS, which can be reused again. Below is the deployment schedule of all drifters in different sites:

![Figure 2. Drifter deployment points, at the mouth of three major rivers in Sumatra and Java Island: Musi river (in South Sumatra Province), Cisadane river (in Banten Province, and Bengawan Solo river (in East Java Province).](image)

| No | Deployment site            | Deployment date     | Number of deployed drifters |
|----|----------------------------|---------------------|------------------------------|
| 1. | Cisadane river*            | 07 Feb 2020         | 2                            |
| 2. | Cisadane river             | 16 Jul 2020         | 5                            |
| 3. | Bengawan Solo river        | 20 Jul 2020         | 5                            |
| 4. | Musi river                 | 23 & 26 Jul 2020    | 6                            |
| 5. | Cisadane river             | 20 Oct 2020         | 6                            |

(*) This deployment is aimed to obtain data which used for calibrating the MOBIDRIFT calculation in Indonesian water.
3. Result and discussion

The near real time position of all MAR-GE/T drifters can be monitored using an interactive map interface of the MDC client portal (Figure 3).

![Figure 3](image-url)

**Figure 3.** Recent position of 21 drifters (accessed from the MDC client portal on August 1st, 2021), after being deployed in three different points of origin in 2020 (see the deployment date and site in Table 1). There are 12 drifters from Cisadane river mouth have been moved toward Indian Ocean, while 5 drifters from Musi river and 4 others from Bengawan Solo are stranded along the coast within Indonesia territory.

3.1. Movement of drifters from Cisadane River

Based on recent data plotted in MDC client portal, there is a drifter deployed on 16th of July 2020 from Cisadane river that move westward exiting Indonesia territory, until reach the east coast of Africa continent, after drifted in the ocean for over a year (Figure 4). Other drifters from the same deployment time, also moved westward but stranded in the coast within Indonesia territory.

On the secondary deployment mission in this river, there are six drifters that deployed in 20th of October 2020 between 10.06 – 10.30 UTC+7. Four drifters are stranded in the region of Seribu Island, while two others headed eastward then moved to south, before stranded on the coastal area of Karawang.

![Figure 4](image-url)

**Figure 4.** Trajectory of a drifter released from Cisadane river, which have reached east coast of Africa continent after a year of deployment.
3.2. Drifters from Bengawan Solo river

Five drifters were released at the Bengawan Solo river mouth in East Java Province on the 23rd of July 2020 between 08.16 – 08.28 UTC+7. All of these drifters were moving toward the same direction to the west, then finally stranded in the east coast of Sumatra Island (Figure 5).

![Figure 5. Trajectory of drifters that deployed at the river mouth of Bengawan Solo.](image)

3.3. Drifter from Musi river

![Figure 6. Drifters deployed at Musi river mouth, move to north then stranded in the east coast of Sumatera Island.](image)
Four drifters were released on the 23rd of July 2020 between 12.18 – 12.30 UTC+7, while two drifters were launched on the following day (26th of July 2020) from the eastern part of the delta at around 07.34 – 07.37 UTC+7 due to technical issue on the previous day (Figure 6). Drifters from the first release were mostly trapped by the river’s current, going upstream and downstream, before getting stranded on the river’s bank. While drifters released on 26th of July 2020, moved to different direction than other drifters previously deployed. The two drifters headed west, where one of them (ID 130182) stranded, while the other (ID 130168) moved to north before getting stranded on the eastern part of Jambi Province.

Plastic pollution is moved throughout the world's oceans by the prevailing winds and surface currents [16]. Here, Figure 7 presents the Southwest (SW) monsoon which generally operates between June and October (upper panel) and the Northeast (NE) operates between December through April (lower panel) [17][18][19]. In this study, particle tracking by using the drifters Cisadane 01 performed by Mobidrift Client Portal (MDC) during SW monsoon, furthermore, shows the longer observation up to NE monsoon. The pattern results in Figure 4 exhibits that the drifters in the period of SW monsoon predominantly persists in the southern Sunda Strait due to South Java Current (SJC), see upper panel in Figure 7) and subsequently flows and relatively steady towards the west to Madagascar, up to the period of NE monsoon. Interestingly, the drifter from Cisadane 01 seems like flows split in two indicating the branch off South Equatorial Current (SEC) into Southwest and Northeast Madagascar Currents.

Figure 7. Schematic of ocean surface currents in the Indian Ocean [17][18][19], during (upper) the SW monsoon season (Jul/Aug); and (lower) the NE monsoon season (Jan/Feb). The following currents are shown and labelled with abbreviations: Southwest Monsoon Current (SMC) and Northeast Monsoon Current (NMC); West Indian Coastal Current (WICC) and East Indian Coastal Current (EICC); Srilanka Dome (SLD); Northeast and Southeast Madagascar Current (NEMC and SEMC); South Java Current (SJC); Indonesian Throughflow (ITF); Somali Current (SC); East African Coastal Current (EACC); North Equatorial Current (NEC); South Equatorial Counter Current (SECC); South Equatorial Current (SEC); Agulhas Current (AC); Leeuwin Current (LC); Flinders Current (FC); and South Indian Counter Current (SICC).
3.4. Comparing the result of drifter tracking method with the forecasting the stranded area of marine debris using Lagrangian modelling.

This study of tracking drifters seems in line with the forecasting result of stranded debris area along Indonesian coast using Langrangian experiment [20]. This forecasting uses CMEMS Surface Merged Ocean Currents (SMOC) product (1/12° - hourly output) released from 21 rivers in Indonesia that categorized as locally polluted rivers, surrounded by high population region and high river discharge. Average simulation result for the year of 2019, indicate that around 60 % particles are stranded on coastal area, 10% of particles are floated at sea, 26 % of particles are moved towards Indian Ocean and around 4% of particles are moved to Pacific Ocean, with the highest occurrence around January- February and June-July. Out of 60% particles that stranded on coastal area, 92,5 % them are stranded on Indonesia territory, while 7,5% of them are stranded on neighboring countries. This result also in accordance with another local based marine debris modelling that conducted in Banten bay, adjacent to Sunda strait, where the most of particles moved around the bay then stranded in the north coast of Java Island, and only a few of them exiting the bay toward Sunda strait during east monsoon [21](Figure 8a and 8b).

**Figure 8.** (a) Tracking drifter study is aligned with the result from forecasting the stranded area of marine debris along Indonesian coastal area based on Lagrangian modelling [20]; (b) This study also in line with the result of local based model, where most of particles moved around the bay then stranded in the north coast of Java [21].

4. Conclusion

The MDC client portal has provided a comprehensive and integrated platform for macro-plastics drift studies at national scale in Indonesia. This platform able to assimilate several data and visualize them in a single interface. In-situ data is acquired from MAR-GE/T drifters which injected with the Argos System, providing near real time of drifters’ movements. Twenty MAR-GE/T drifted were released from three selected rivers (e.g., Cisadane, Bengawan Solo, and Musi river). Some drifters were reused for several missions, thus providing more movement data which can be useful to calibrate future drifting simulation. All acquired data have been recorded and stored in the MDC portal, will allowing Indonesian researcher and authorities to gain a better understanding of plastic litter movement pattern on the ocean, and provide indicative areas which are mostly affected by plastic litter.

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