Performance of float artificial debris (FAD) with Lagrangian concept

Noir P. Purba, Ibnu Faizal

Department of Marine Science, Faculty of Fisheries and Marine Science, Padjadjaran University, Bandung, West Java, Indonesia. Corresponding author: N. P. Purba, noir.purba@unpad.ac.id

Abstract. The design of a tested surface drifter that is used to measure the spread of marine debris is presented. Two FADs were tested and planted a GPS/GPRS tracker unit to transmit their positions. FAD2 was modified from FAD1 with some changes in its design. Both laboratory and field tests involved buoyancy, stability and data transmit. The test results in the field showed that FAD2 was\ better than FAD1. Its design was capable to represent floating marine debris with certain sizes. The instruments were compact, nearly accurate, cost-effective, simple to manufacture and are easily adaptable in the open ocean and coastal regions. The speed and direction indicated by FAD1 and FAD2 were similar with the direction of wind and ocean current.
Key Words: trajectory, instruments, marine debris, RHEA lagrangian, ocean current.

Introduction. In this day and age, waste (garbage/litter/debris) in the ocean becomes a serious problem (Purba et al 2018a). We use debris as a specific term of waste in the ocean. The debris in the ocean is very complex and dependent on many parameters such as wind, ocean currents, waves and other external factors (Ramos et al 2018). At the present time, to figure out the spread of debris as particles in the sea, a model approach (Carlson et al 2017; Handyman et al 2019), float tracking (Purba et al 2017; Van Sebille et al 2012), in situ sampling (Gutow et al 2018), satellites (Moy et al 2018), and numerical models (Politikos et al 2017; Jasmin et al 2019) have been carried out.

In Indonesia, marine debris comes from many sources; not only from inner Indonesia itself but also from other surrounding countries. Sea currents flow from the north of Indonesia and bring marine debris along with it into Indonesia. As the current exits in the south (Sawu, Lombok Strait, Sunda Strait), debris are distributed to the Indian Ocean. Marine debris has been already discovered in water columns (Hiwari et al 2019), beaches (Purba et al 2018b), ecosystems (Maharani et al 2017), fish and sediments (Septian et al 2018).

The distribution could be monitored by a Lagrangian instrument. This paper focuses on the development of a simple instrument (Artificial Debris) to analyze the spread of debris/pollutant with Lagrangian analysis (Ohlmann et al 2005). It has been proven that Lagrangian trajectory analysis is a very valuable tool in predicting the fate and origin of specific water masses including passive particles (Jönsson et al 2011). Since the advent of satellite telemetry and positioning in the late 1970s, satellite-tracked drifters have been used profusely and successfully to measure near-surface currents in all the world's ocean basins and most semi-enclosed seas (Poulain et al 2009; Torsvik 2016).

Float Artificial Debris (FAD) is an instrument designed to examine the displacement of Lagrangian marine waste (following water parcels). It can also be used to monitor waste or particle movements that are thrown into the sea from the coast (Meyerjürgens et al 2019). The data obtained from this tool's recording can be processed into a point per point location. The drifters used in the water are floating instruments installed with different type of GPS devices, allowing the positions of the trajectories/path to be retrieved in real-time or near real-time (Gerin et al 2018).

In the present paper, the performance of FAD with its low cost and easy to operate was used to study marine debris' pathways, especially for macro debris with size more than 2.5 cm (Lippiatt et al 2013). This paper's objective is to build an FAD that can be used in the ocean's complex system and aquatic conditions. This paper also discusses its future development regarding its shape and data processing.

Material and Method

Description of the study sites. This study was conducted by testing two FADs prototypes that have different shapes. It was approached by conducting laboratory and field tests. Laboratory tests were carried out to test the FAD's balance and position, and field tests were used to see the equipment's propagation in actual conditions.

Design and system. For this purpose, FAD1 was made up of resin and FAD2 of Poly Lactic Acid (PLA). ADs also have small housing (Table 1). The device that sends the position is a waterproof Mini A8 ST-901 GPS Tracker. The electronics in this new drifter have been carefully selected from various GPS trackers on the market. The battery can last up to 30 hours of GSM 2G with a weight of about 30 g. The size was 43.2 x 32 x 13.6 mm. This component consisted of 1) Global Positioning System (GPS), 2) Li-Ion Battery, 3) Signal transmitter, and waterproof housing. The GSM signal used was the Telkomsel provider because it has the most extensive range in Indonesia's territory. It was also equipped with an SOS signal when no position can be determined, for instance, due to poor or lost signal.

Table 1

Differences in the construction shape of floating artificial debris

Parameters	*Shape*	*System*	*Weight*	*Material*	*Accessories*
FAD1	Round	GPS	680 g	Resin	NA
FAD2	Tube	GPS	250 g	PLA	~0.6 g/piece

This function is to find out the latest position of AD. First, register the card and set it to record position data. The GSM card must also have phone credit. One data transmission costs 12 USD. Then, set the time to send data according to the time and interval desired by the user. In this case, the data was sent every 60 seconds. Data delivery testing was carried out for 10 minutes to ensure that the signal delivery runs smoothly. The instrument was then released into the sea as an artificial waste that floats on the surface of water. Users can monitor the movement of artificial debris through mobile phones that are used as data recipients from AD. The data received by the user is in the form of short message service (SMS) which contains data of latitude, longitude, time and speed that can be seen at GoogleMaps (https://www.google.com/maps) in real-time.

Laboratory and field testing. Tests were carried out in the laboratory and in the field. Laboratory tests were carried out by creating FAD, testing buoyancy in the pond and testing data transmission by GPS. These tests were also used to make sure that 2/3 of the instrument is below waterline. FAD1 was made manually whereas FAD2 was made by 3D printing. The experiment was conducted in two areas located in Seribu Islands, Jakarta (Pramuka Island and Untung Jawa Island). The oceanographic currents are mostly affected by winds and tides. For comparison, a standard float tracking was used to examine the trajectories. This area was chosen because of the frequent "waste shipment" to the islands. Waste in beaches usually arrive in the morning (during high tide) and spread to other islands in the afternoon during low tide.

Analysis. The analysis was carried out by observing the position sent by the GPS tracker in Google Earth with the handheld GPS position. Another analysis was performed by visual observations in the field, including the casing's shape, resistance and buoyancy. To validate the drifter's design, this model had been equipped with standard commercial functions for its swallow water characterization and drifting behavior, and was then compared to other widely-used float tracking.

Results

Design and construction. The drifters were designed for use in all types of water. FAD1 and FAD2 had different shapes in which FAD1 is round and FAD2 is tube-shaped (Figure 1). Apart from their difference in shape, FAD2 was also equipped with four wings and ballast at the bottom which can be added or reduced. This is useful to adjust the weight of various debris in the ocean. Both FADs allow GPS are allows tracker to be placed inside them and easy to release. Moreover, it will be closed to protect GPS tracker (GPS and GSM) from the water and also ensure that the signal is also received by the users.

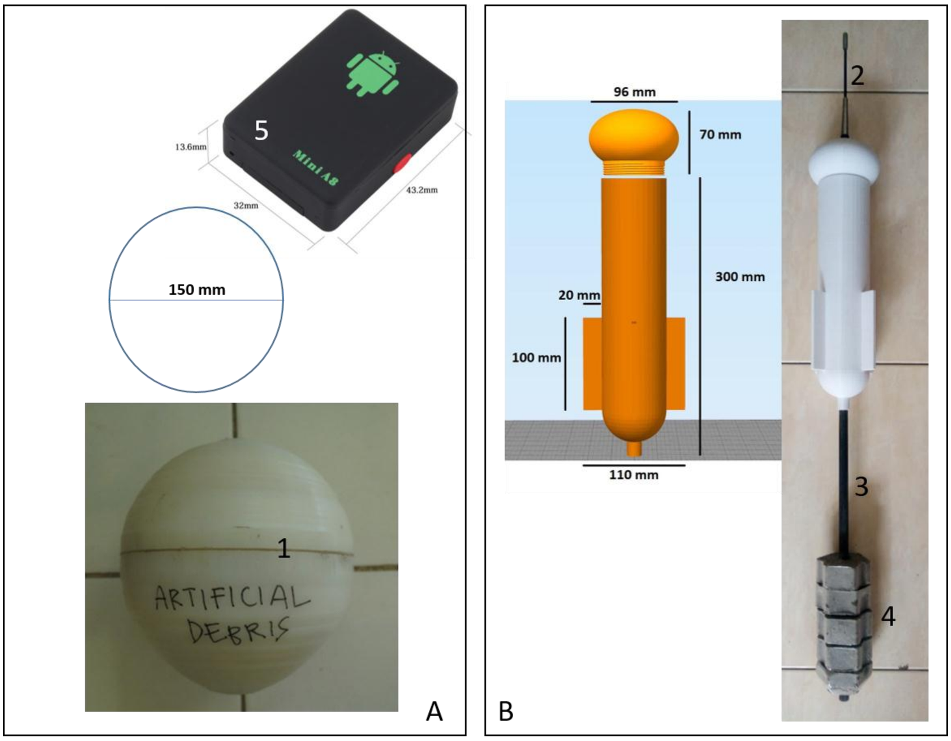

Figure 1. Construction of floating artificial debris, (A) Boundary FAD, (B) Cube FAD and 1) inserted GPS, 2) Antenna, 3) Bottom pillars, 4) Ballast, 5) GPS tracker.

For FAD1, the casing can be opened in the middle by rotating it. Inside the casing, there is a foam as a place where the GPS tracker attaches. For FAD2, it can be opened from the top. Antenna was installed in FAD2 as a signal amplifier. However in experiments, the data acceptance without signals was sufficiently good. For FAD1, the center of gravity is in the middle whereas for FAD2, the lower cylinder part is the heaviest element of the drifter. Its long shape allows the buoy's center of gravity to be below. The same details were given by (Mackas et al 1989) where the tool's stability needed to be maintained against extreme wave interference and other disturbances.

Laboratory and field testing. Signal delivery verification was carried out in laboratory and in the field. In the laboratory, the GPS tracker lighted up and sent signals every 30 seconds for 12 hours. Before it was tested at sea, a signal delivery attempt was carried out from the GPS tracker. The test was carried out on land by comparing a Garmin GPS handheld and GPS tracker to mark certain locations such as docks, houses, and other past points which were then marked and viewed in Google earth (Figure 2).

Figure 2. The testing positions between GPS tracker and GPS handheld Garmin A) 12 hours in the laboratory, B) field testing.

The tests in the laboratory indicated that the shown location was the same as the building's position in Google Earth. Also, the GPS Tracker continuously sent the position information every 30 seconds. In the field, there were 13 points tested for comparison. From these test points, the difference in distance from the desired pathways was around 1-2 m. The signal transmission by the GPS tracker was also decent and continuous. Tests for FAD1 and FAD2 were carried out around the Thousand Islands. Tests for FAD 1 were held in November 2017 and FAD2 in May 2018 (Figure 3). The water conditions were affected by the current movements caused by wind and tides. The ocean surrounding is also shallow water with depth around 10 to 60 meters.

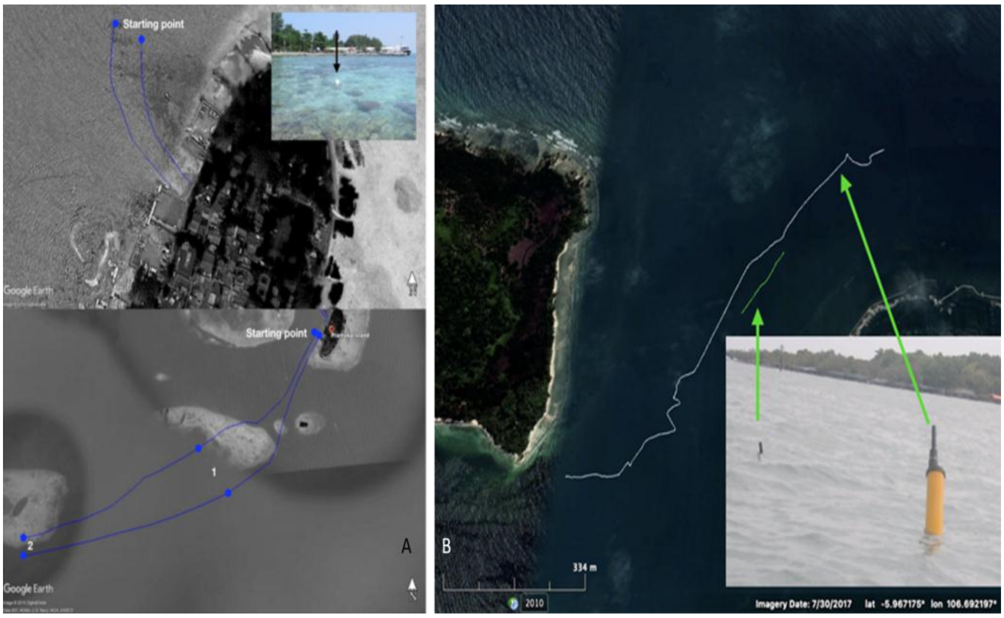

Figure 3. AD pathways A) AD1 at Pramuka Island, B) AD2 with float tracking at Untung Jawa Island.

The release of AD1 was carried out around the dive spot near the Pramuka Island fishing pier. Before monitoring, a binocular was prepared for visual observation and verification of signal delivery with a mobile phone. Observation started at 1:00 p.m. First, AD was released and its movement was then recorded both visually and by data retrieval sent via text messages. In the first experiment, AD was stranded on the coast because the ocean currents moved towards the southeast at the time. The second experiment was carried out around the port to the south from the first experiment. It was then observed as far as possible. In this second observation, the AD disappears and does not send any signal after 2 hours. Based on its direction at the time, it was predicted that it headed southwest of the island. AD2 testing was held in different locations around the island of Untung Jawa. The speed shown in the two instruments were insignificantly different. The AD1's speed during the experiment was in the 0.5-1.2 m s^{-1} range, whereas AD2 was around 0.6-1.2 m s^{-1} (Table 2).

Table 2

Instruments' velocity compared to wind and ocean currents

Parameters	*Direction*	*Mag (m/s)*	*Wind direction*	*Current direction*
FAD1	*SE- SW*	0.5–1.2	SW - S	SE – SW
FAD2	*NW*	0.6–1.2	NW	NW

For signal delivery verification, the test sender was also tested before the instrument was released. It was also carried out by releasing the standard float tracking. This experiment was held for about 2 hours by boat to follow the FAD's movements. The FAD's and the float tracking's movements had the same direction, which was to the northeast. This was subsequent to the current's direction and conditions at the time. In field observations, FAD movements were slower than float tracking.

Conclusions. The FAD construction and design was realized with low cost and tested both in laboratory and ocean. FAD2's construction and design were better than of FAD1. However, FAD1 and FAD2 can be used to track marine debris with modifications. The problems in FAD1 was in its casing; bigger and heavier. For those problems, the casing can be changed with lighter and thinner materials. GPS shows the right position or has a low error rate. However, for more precision, GPS can be replaced with other suitable trackers that can be found at the market. For territorial waters where no signal can be found, it can be replaced by satellites. It has a long battery life; 1 battery lasts 8-10 hours with data sent every 60 seconds. The direction of AD also showed the same pathway as marine debris during field observations. The trajectories of these instruments generated information of Lagrangian concept from coastal areas, shallow water and the open sea.

This study emphasized the problem that the material used for the casing is still a plastic-type material. This creates a new problem in which if the AD is lost, it will become a waste in the ocean. For future research, it may be possible to develop organic materials as a casing.

Acknowledgments. The FAD preparations and field testing were carried out by P. G. Mulyani, Isnan F. Pangestu, Candra Anggun and Nadhira A. Wardhani from Diving Clean Action. We used Marine Laboratory Research (MEAL), for testing the instruments. We also thank anonymous reviewers who have provided input for this article.

References

Carlson D. F., Suaria G., Aliani S., Fredj E., Fortibuoni T., Griffa A., Russo A., Melli V., 2017 Combining litter observations with a regional ocean model to identify sources and sinks of floating debris in a semi-enclosed basin: The Adriatic Sea. Frontiers in Marine Science 4(78):1-16.

Gerin R., Zennaro M., Rainone M., Pietrosemoli E., Poulain P. M., Crise A., 2018 On the design of a sustainable ocean drifter for developing countries. EAI Endorsed Transactions 4(13):1–9.

Gutow L., Ricker M., Holstein J. M., Dannheim J., Stanev E. V., Wolff J. O., 2018 Distribution and trajectories of floating and benthic marine macrolitter in the south-eastern North Sea, Marine Pollution Bulletin 131:763–772.
Handyman D., Purba N. P., Pranowo W., Harahap S., Faizal I., Yuliadi L., 2019 Microplastics patch based on hydrodynamic modeling in the North Indramayu, Java Sea. Polish Journal of Environmental Studies 28(1):1–8.
Hiwari H., Purba N. P., Ihsan Y. N., Yuliadi L. P., Mulyani P. G., 2019 Condition of microplastic garbage in sea surface water around Kupang and Rote, East Nusa Tenggara Province. Prosiding Seminar Nasional Masyarakat Biodiversitas Indonesia 5(2):165-171.
Jasmin H. H., Purba N. P., Harahap S. A., Pranowo W. S., Syamsuddin M. L., Faizal I., 2019 The model of macro debris transport before reclamation and in existing condition in Jakarta Bay. Jurnal Ilmu dan Teknologi Kelautan Tropis 11(1):131-140.
Jönsson B. F., Döös K., Myrberg K., Lundberg P. A., 2011 A Lagrangian-trajectory study of a gradually mixed estuary. Continental Shelf Research 31:1811-1817.
Lippiatt S., Opfer S., Arthur C., 2013 Marine debris monitoring and assessment. NOAA Technical Memorandum NOS-OR&R-46, 77 p.
Mackas D. L., Crawford W. R., Niiler P. P., 1989 A performance comparison for two lagrangian drifter designs. Atmosphere-Ocean 27(2):443–456.
Maharani A., Handyman D. I., Salafy A., Nurrahman Y., Purba N. P., 2017 Macrodebris condition in Mangrove Untung Jawa island, Kepulauan Seribu. BIG Seminar Proceedings, pp. 55-64.
Meyerjürgens J., Badewien T. H., Garaba S. P., Wolff J. O., Zielinski O., 2019 A State-of-the-art compact surface drifter reveals pathways of floating marine litter in the German Bight. Frontiers Marine Science 6(58):1-15.
Moy K., Neilson B., Chung A., Meadows A., Castrence M., Ambagis S., Davidson K., 2018 Mapping coastal marine debris using aerial imagery and spatial analysis. Marine Pollution Bulletin 132:52–59.
Ohlmann J. C., White P. F., Sybrandy A. L., Niiler P. P., 2005 GPS-cellular drifter technology for coastal ocean observing systems. Journal of Atmospheric and Oceanic Technology 22:1381–1388.
Politikos D. V., Ioakeimidis C., Papatheodorou G., Tsiaras K., 2017 Modeling the fate and distribution of floating litter particles in the Aegean Sea (E. Mediterranean). Frontiers in Marine Science 4(191):1-18.
Poulain P. M., Gerin R., Mauri E., Pennel R., 2009 Wind effects on drogued and undrogued drifters in the eastern Mediterranean. Journal of Atmospheric and Oceanic Technology 26(6):1144–1156.
Purba N. P., Harahap S. A., Prihadi D. J., Faizal I., Mulyani P. G., Fitriadi C. A., Pangestu I. F., Atmoko P. D., Alfath A., Sitio J. T., 2017 [Development of lagrangian instrument GPS drifter combined (GERNED) for ocean observation]. Jurnal Kelautan Nasional 12(3):109–116. [In Indonesian].
Purba N. P., Apriliani I. M., Dewanti L. P., Herawati H., Faizal I., 2018a Distribution of macro debris at Pangandaran Beach, Indonesia. World Scientific News Journal 103(7):144–156.
Purba N. P., Ihsan Y. N., Faizal I., Handyman D. I. W., Widiastuti K. S., Mulyani P. G., Tefa M. F., Hilmi M., 2018b Distribution of macro debris in Savu Sea Marine National Park (Kupang, Rote, and Ndana Beaches), East Nusa Tenggara, Indonesia. World News of Natural Sciences 21:64-76.
Ramos A., Purba N. P., Faizal I., Mulyani Y., 2018 Microplastic tracking from Pacific garbage to Northern Indonesia Sea. Jurnal Perspektif Pembiayaan Dan Pembangunan Daerah 6(1):87–96.
Septian F. M., Purba N. P., Agung M. U. K., Yuliadi L. P. S., Akuan L. F., Mulyani P. G., 2018 Microplastic spatial distribution in sediment at Pangandaraan Beach, West Java. Journal Geomaritim Indonesia 1(1):1-8.
Torsvik T., 2016 Data processing and performance testing of a low-cost surface drifter design for use in coastal waters. Proceedings of the Estonian Academy of Sciences 65(1):58-67.

Van Sebille E., England M. H., Froyland G., 2012 Origin, dynamics and evolution of ocean garbage patches from observed surface drifters. Environmental Research Letters 7(4):1-6.
*** https://www.google.com/maps

Received: 24 September 2019. Accepted: 19 December 2019. Published online: 26 December 2019.
Authors:
Noir Primadona Purba, Padjadjaran University, Faculty of Fisheries and Marine Science, Department of Marine Science, Indonesia, West Java, 40600 Bandung, Ir. Sukarno st. Km. 21, e-mail: noir.purba@unpad.ac.id
Ibnu Faizal, Padjadjaran University, Faculty of Fisheries and Marine Science, Department of Marine Science, Indonesia, West Java, 40600 Bandung, Ir. Sukarno st. Km. 21, e-mail: ibnu.faizal@unpad.ac.id

How to cite this article:
Purba N. P., Faizal I., 2019 Performance of float artificial debris (FAD) with Lagrangian concept. AACL Bioflux 12(6):2236-2242.