Marine Debris Distribution, Variation and Seasonal Changes along the Coast and on Sea Surface of the Kagoshima Bay

Benjamin Dotto MAJANGA[1], Shigeru FUJIEDA[2], Ryuichiro NISHI[3], Kazunori HOSOTANI[4]

[1]United Graduate School of Agricultural Sciences, Kagoshima University
(Shimoarata 4-39-20 (413), Kagoshima, 890-0056, Japan)
E-mail:benjadoto911@gmail.com
[2]Member of JSCE, Former Professor, Faculty of Fisheries, Kagoshima University
(3-4-12-202, Minamimachi, Kokubunji, Tokyo, 185-0021, Japan)
E-mail: shifloc@nifty.com
[3]Professor, Faculty of Fisheries, Kagoshima University
(4-50-20Shimoarata, Kagoshima-shi, Kagoshima890-0056. Japan)
E-mail:nishi24@fish.kagoshima-u.ac.jp
[4]Member of JSCE, Associate Professor, National Institute of Technology, Tsuyama College
(6-24-1Numa, Tsuyama-shi, Okayama, 708-0824. Japan)
E-mail:hosotani@tsuyama-ct.ac.jp

Marine debris issues have gained a significant concern recently due to their impacts to coastal and marine environments. Knowledge on their abundance, distribution and seasonal variation are still limited in many aquatic environments including Kagoshima bay. This study was conducted in three phases from the year 2010 to 2014. Field study in Oosumi peninsula and along Kotsuki River was conducted on November, 2010 to investigate the abundance and distribution of micro size debris. Then, in Kagoshima bay three field studies were carried out to investigate spatial distribution and seasonal changes of marine debris along its coastline and on sea surface from the year 2011 to 2014. Kagoshima bay opens to the south of Kyushu island and is affected by Kuroshio current which probably carries marine debris into the bay. In addition there are several major rivers which carry debris into the bay. The size of the bay is similar to Tokyo bay, therefore field studies in and along its coastline can be representative study to reveal qualitative and quantitative characteristics of marine debris inside a bay in Japan. As a result, EPS fragments dominated the distribution in almost all surveyed beaches (over 90%). Rainfall and natural disasters (i.e. typhoon) contributed significantly to higher deposition levels of micro debris on beaches.

Key Words : *Plastics, EPS fragments, Marine debris, Kagoshima bay*

1. PREFACE

Marine debris as shown in Fig. 1 remains a difficult issue to address in many countries due to their varied sources, distribution and seasonal changes causing difficulties in the source prediction and likewise its management[1)]. Any trash has the potential to become marine debris if not well managed. Approximately 1.5 million tons/year of plastics were produced globally during 1950s' and the production raised to 250 million tons by 2007 with 10% increase annually[2)]. No reliable estimates were provided for the amount of plastics which finally end into marine environment.

Fig. 1 An example of deposition of marine debris on sandy beach

Plastic debris in oceans was mentioned as among the major ten global environmental challenges highlighted over the past decade[3)]. International Coastal Cleanup (ICC) has identified fragments of foamed plastic, EPS (Expanded Polystyrene) as a major component of beach litter around the world.

In Kagoshima prefecture 65 beaches were surveyed from 1998-2000 whereby EPS fragments dominated the distribution with EPS floats predicted as the major source [4,5)]. The size of the bay and the length of its coastline are 1,130 km^2 and 330km respectively. Since the last study, regulations on debris had been changed and social activities to reduce marine debris levels had been conducted. Therefore, additional studies were conducted in Kagoshima bay to assess the spatial distribution and investigate variation and seasonal changes of micro and macro size debris within and out of the bay.

2. METHODOLOGY

The first survey started on 15^{th} November, 2010 by collecting sand samples on 12 stations in Shibushi bay and along the coastline of Oosumi peninsula as shown in Fig. 2.

The second survey was conducted along the course of Kotsuki River on 22^{nd} November, 2010. This River run through Kagoshima city which is the most populated among other cities around the bay. Sand samples containing the debris were collected from 7 stations as shown in Fig. 3.

The main survey was conducted within the bay in November, 2011 in which sand samples were collected from 26 accessible beaches as shown in Fig. 4. Monthly monitoring for 9 selected beaches was conducted from April, 2013 to March, 2014. These 9 stations were chosen because of the higher levels of deposited debris and the location within the bay as observed in Figs. 4 and 5. The same sampling and analytical procedures were applied to every station. A quadrant was set on the strand line of a sandy beach, a location was recorded and a sand sample was collected within 40x40 cm^2 area and 5 cm deep. Sand samples from all stations were taken to the laboratory and subjected to density separation using sea water. Floating items were scooped out and left to dry.

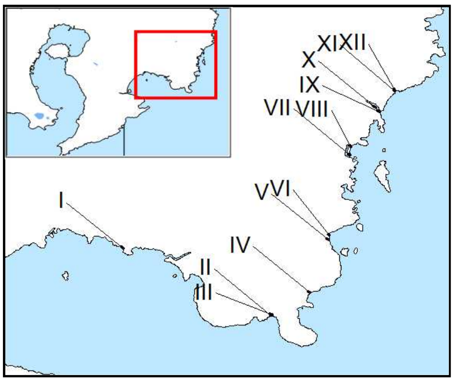

Fig. 2 The map showing 12 sampling stations conducted in Shibushi bay and along Pacific coast in Oosumi Peninsula

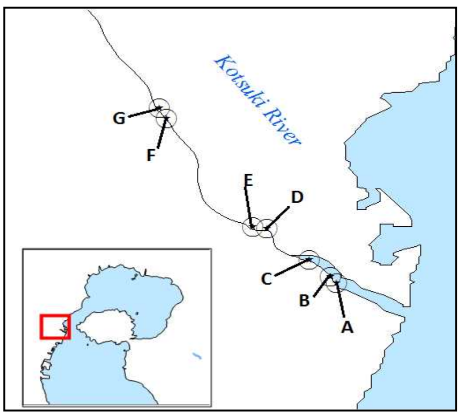

Fig. 3 The map of Kotsuki River showing the sampling stations

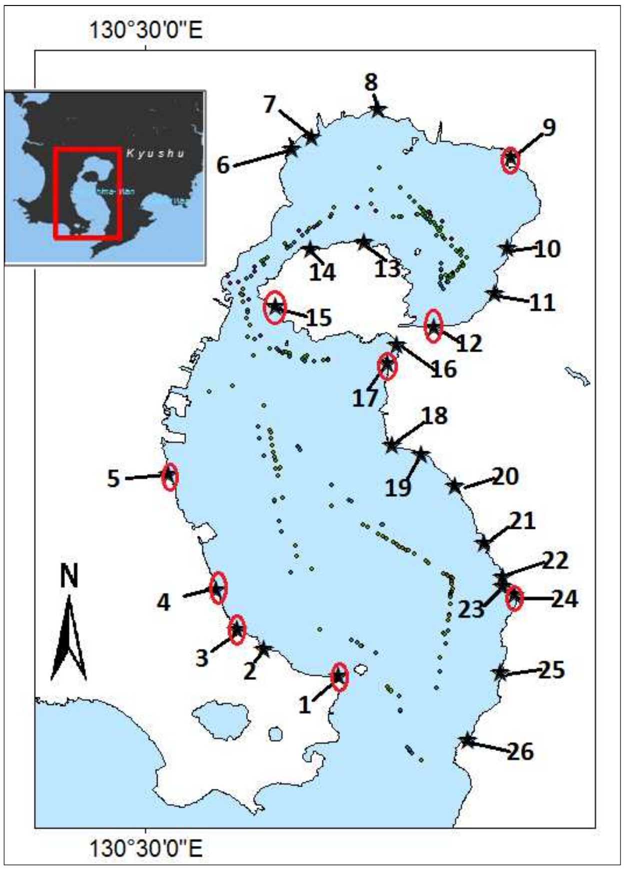

Fig. 4 The map of the Kagoshima bay showing 26 beaches where samples were collected, 9 monitored stations (red cycles) and locations of observed drifting debris

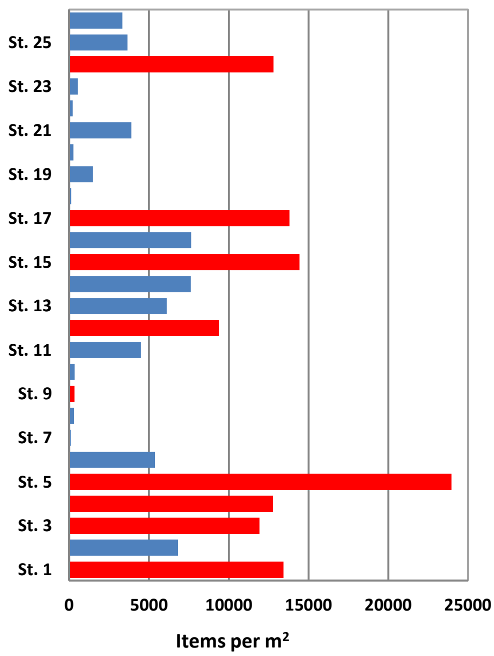

Fig.5 Micro debris densities per station surveyed on November 2011 with 9 monitored stations in red bars.

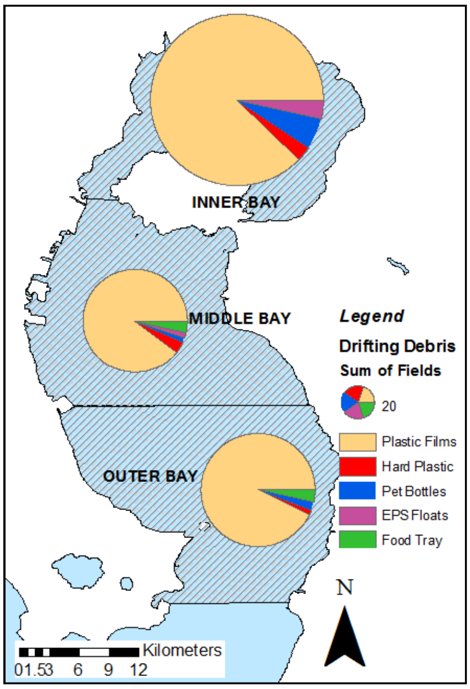

Fig. 6 The map showing the amounts for the drifting debris, the size of the cycle corresponds to the total count and the colors indicating individual items

Size categorization was done by sieving machine applied with 1 mm, 1.5 mm, 2 mm, 2.8 mm, 4 mm and 8 mm mesh screens. The machine runs for 2 minute at 1 mm amplitude[5,6]. A magnifying glass with fluorescent light installed beneath was applied to illuminate and view the samples. Samples were then sorted and counted manually. For this study, micro size debris is defined as debris between 1 mm and 8 mm size range. EPS fragments and the other 5 items which showed higher counts were used for further statistical analysis. Hard plastic fragments, capsules of artificial fertilizers, artificial grass fragments, plastic film fragments and resin pellets were referred to as the top 5.

Onboard visual counting was also conducted to investigate macro size debris spatial surface distribution in the bay on January, April, July and October, 2014. Macro size debris in this study is defined as the items of 5 cm size and above. Observed items at a distance of 30 m from the moving vessel were counted and their locations were recorded simultaneously. To consider the spatial distribution, the bay was then divided into 3 regions, Inner bay (261 km^2), Middle bay (345 km^2) and Outer bay (355 km^2) as shown in Figs. 4 and 6.

SPSS ver20 and ArcMap of the ArcGIS ver10 were used to conduct a statistical analysis on spatial and monthly distribution.

3. RESULTS

(1) Surveys in Oosumi peninsula and Kotsuki River

Survey in Oosumi peninsula showed a total of 13,489 items per m^2. EPS fragments dominated to as much as 70%. Regarding the top 5, resin pellets showed the highest (14%) followed by hard plastic fragments (13%).

Resin pellets as shown in Fig. 7 are in higher levels among the top 5 out of the bay contrary to the situation within the bay as shown in Fig. 10.

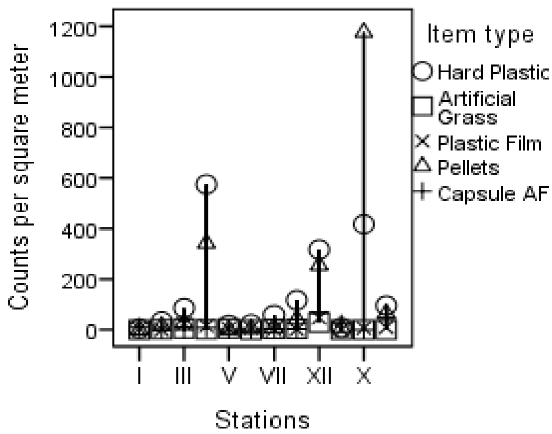

Fig. 7 Spatial distribution of top 5 items on stations out of the bay

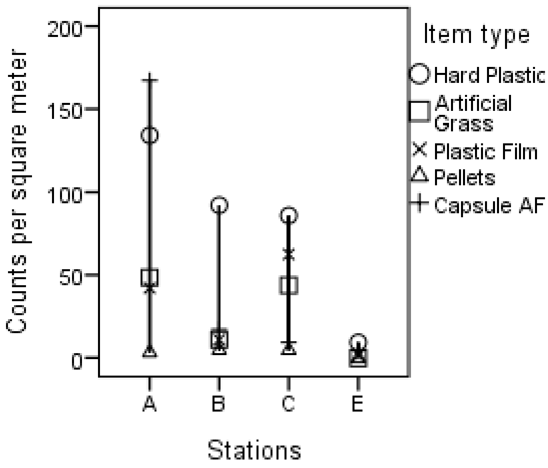

Fig. 8 Spatial distribution of top 5 items along Kotsuki River

EPS fragments during the Kotsuki River survey dominated the distribution to as much as 79% out of 2,822 items per m^2 total density. Station A which is located at the river mouth, showed highest EPS counts and the amounts decreased upstream. Regarding the top 5, hard plastic fragments (9%) and capsules of artificial fertilizer (6%) showed the highest spatial densities as shown in Fig. 8.

(2) Micro debris in the Kagoshima bay

a) The 26 surveyed stations

It is shown that 165,100 fragments per m^2 were collected in total. EPS fragments account for 92% of total items. Thus, EPS fragments were the most dominating marine debris along the bay. The 9 monitoring stations were then chosen among the 26 stations (Figs. 4 and 5).

b) The 9 Monitoring Stations

Monthly collection revealed a total of 1,924,956 fragments per m^2 in a year at 9 monitoring stations. EPS fragments dominated as much as 95%. The deposited densities (number of items per m^2) vary with time (months) and location (stations). The highest average density was observed in station 15 (19.7%) followed by station 12 (17.3%), station 24 (13.6%) and station 1 (12.9%). September showed the highest average density (13.6%) followed by December (12.2%), June (10.5%) and April (10.2%) as shown in Fig. 9

The other items that showed significant counts besides EPS Fragments are hard plastic (1.55%), capsules of artificial fertilizer (1.32%), artificial grass (1.01%), plastic films (0.35%) and resin pellets (0.29 %). Contrary to EPS having a peak on September, the Top 5 items showed the highest density on June as shown in Fig. 10.

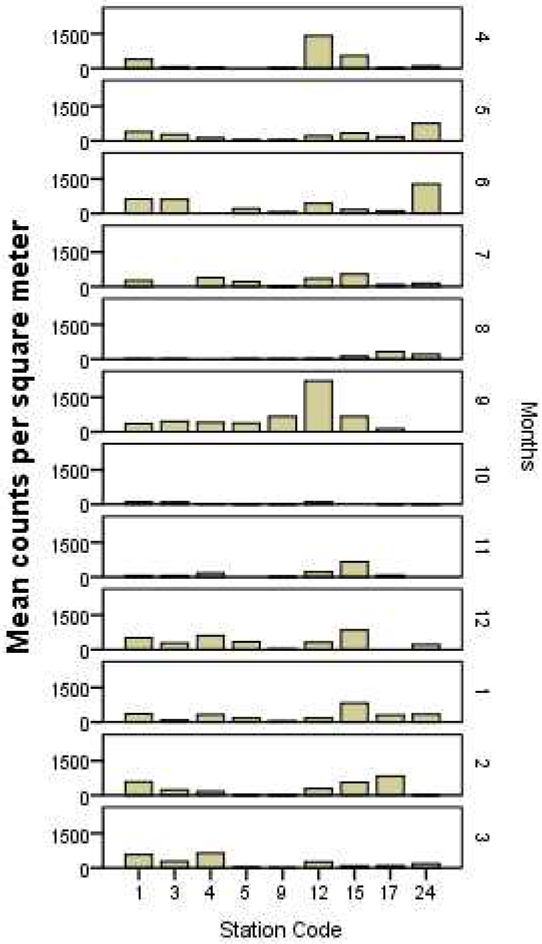

Fig. 9 Average monthly densities for EPS fragments deposited per station in 9 monitored stations

c) Rainfall Effect

The monthly rainfall in Kagoshima city is shown in Fig. 11. June is the rainy season and recorded high rainfall as much as 430 mm in total. The study area received harsh weather conditions during typhoons. Kagoshima bay received two significant typhoons in September, 2013 with the strongest on the 3rd. Due to field experience of debris collection; it is assumed that much rainfall causes higher deposition densities of marine debris on sandy beaches. Therefore amounts of rainfall and marine debris were correlated to as much as 0.987 coefficient of determination for the top 5 as shown in Fig. 12.

(3) Visual observation on drifting debris in Kagoshima bay

The visible drifting debris in the bay showed significant amounts of plastic films, hard plastic pieces, pet bottles, EPS floats and food trays constituting a total of 947 items. Plastic films dominated as much as 89% of the total observed items.

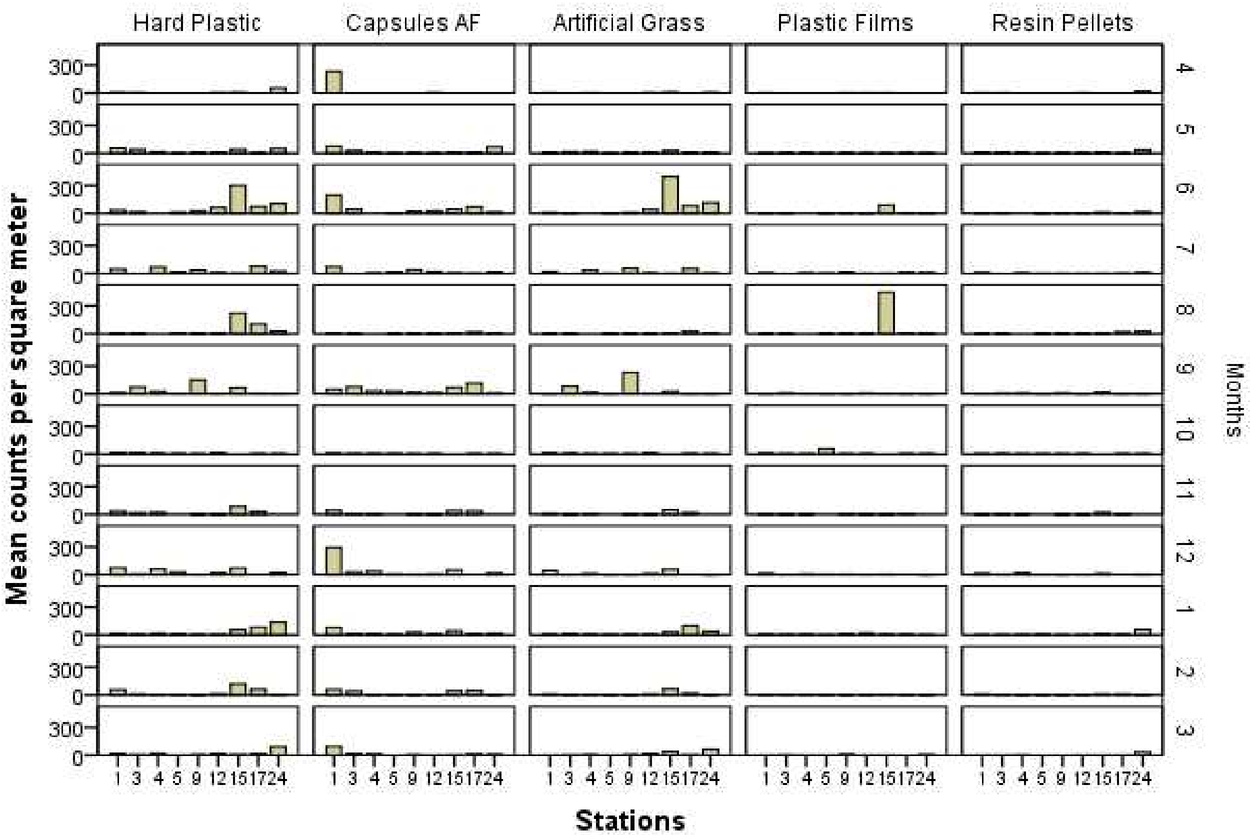

Fig. 10 Average monthly densities for Top 5 items deposited at 9 monitoring stations in a year

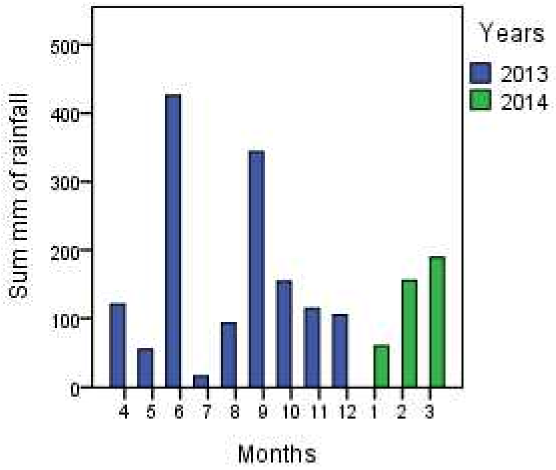

Fig. 11 Rainfall distribution in Kagoshima city.(Source: Japan Meteorological Agency)

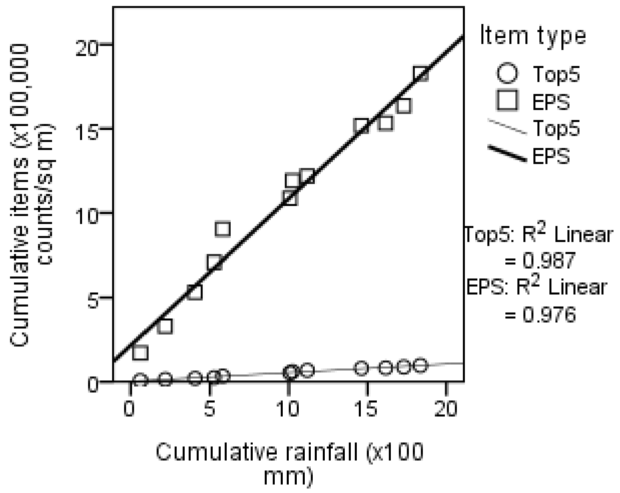

Fig. 12 Relationship between rainfall to the amounts of EPS and top 5 items from 9 stations in a year at 95% CI

There is a narrow channel connecting the inner bay and the middle bay with Sakurajima Mountain separating the two. It was shown that there were more of drifting debris in the inner bay (56%), less in the outer bay (24%) and very few in the middle bay.

4. DISCUSSION

EPS fragments continue to be the leading environmental concern within the bay and the surrounding area. Previous studies identified the higher existing deposition densities and proposed their potential sources [4,5,6,7)]. This study was conducted to further determine their varied distribution in time and in space within the bay.

EPS fragments dominated in all the stations. EPS fragments at stations 15 and 12 showed much deposition densities. These stations are located near the fish farms which can be a source of exposed (uncovered) EPS fenders and buoys. The higher deposition of EPS at station 12 was probably caused by 2 typhoons incidences in September, 2013. Generally speaking, rough ocean waves could enhance the breakdown of exposed EPS floats into pieces which weather to smaller fragments and finally drifted into nearby beaches. June was second from September in showing higher deposition densities of EPS fragments. June is the major rainy season in the Kagoshima bay. The highest deposition densities of the items in the Top 5 particularly hard plastics, capsules of artificial fertilizer and artificial grass fragments were as well observed in this season (June). In this study, deposition densities of marine debris on sandy beaches in September and June were significantly higher than other months during the survey. The correlation between rainfall and debris deposition showed significant relationship with the Coefficient of determination (R^2) of 0.987 and 0.976 for the top 5 and EPS fragments respectively as shown in Fig. 12.

Station A located nearest to the Kotsuki River mouth accounted for the highest levels of EPS fragments and the amount decreased upstream. Regarding the top 5, hard plastics and capsules of artificial fertilizer dominated along the river. This suggests that they are probably land based debris.

The EPS fragments also dominated in almost all stations during surveys out of the bay although in lower levels compared to those within the bay. However, spatial density of pellets was significantly high in those regions than within the bay. Therefore, most of resin pellets are transported probably into the bay from the outer sea by ocean currents.

More than half of the visible drifting debris was found in the inner bay with higher levels of plastic films and pet bottles than in other parts of the bay. This observational result is probably due to the discharge of debris into the inner bay by rivers and streams. The inner bay is surrounded by highly populated cities around than other parts of the bay. Furthermore, the narrow channel between the inner and middle bay allows at the lower rate of debris exiting the inner bay. Tidal currents could probably contribute to discharge in or out of the inner bay.

5. CONCLUSION AND RECOMMENDATION.

EPS fragments are a major environmental issue within the bay. Its distribution was mostly affected by rough ocean waves and natural disasters such as typhoon and heavy rainfall in September and June respectively. The exposed EPS fenders and buoys in ports and fish farms should be well managed as the countermeasure to this problem. The use of conventional fenders and buoys is proposed to be the convenient solution. However, hard plastic fragments, artificial grass fragments and capsules of artificial fertilizer are mostly land based and the levels are still low and in limited distribution, but they can build up and spread out overtime. Their distribution was subject to proximity from their land sources and was highly influenced by heavy rainfall. Nevertheless, the accumulation of macro debris along the inner bay was suggested to be due to ocean currents that carry them along its course to the inner bay. More research is recommended to ascertain the situation.

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