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INVESTIGATION OF CURRENT SITUATION OF DERELICT FISHING NETS IN MALAYSIA

Z. F. CHIN[1], H. L. CHOO[1,*], C. H. LEE[1], J. K. P. TAN[1], J. WANG[2]

[1]School of Engineering, Taylor's University, Taylor's Lakeside Campus,
No. 1 Jalan Taylor's, 47500, Subang Jaya, Selangor DE, Malaysia
[2]Department of Chemical Engineering and Applied Chemistry, Aston University,
Birmingham, B4 7ET, United Kingdom
*Corresponding Author: huileng.choo@taylors.edu.my

Abstract

Since the introduction of synthetic polymers, many fishing gears have incorporated these materials due to their excellent mechanical properties. However, these synthetic polymers take more time to decompose and remain in the ocean for a long time. Over the years, there is also an increasing amount of abandoned, lost, and discarded fishing gear (ALDFG) appearing in the ocean, causing harm to marine animals. Malaysia is also facing the issue of ALDFG where they are causing problems to marine animals and coral reefs. A survey was conducted with derelict fishing net (DFN) collectors and fishermen as preliminary data on the situation of the DFN in Malaysia. DFN collected by Reef Check Malaysia was obtained and Fourier Transform Infrared (FTIR) Spectrometry was conducted to identify the material of the DFN. From the survey results, these DFNs in Malaysia were collected through beach clean-ups or by diving teams. Additionally, the highest amount of DFN collected in a year was more than 7 tons. Currently, the collected derelict fishing nets in Malaysia are being disposed of using incineration or landfills instead of recycling. As for the FTIR test, the results showed that the DFN were made from high-density polyethylene. In this study, the information gathered from the survey could provide insights on the current situation on the amount of DFN in Malaysia and the current retrieval methods. In the future, the collected DFN will be mechanically recycled and tested for their mechanical and thermal properties.

Keywords: Derelict fishing nets, Marine debris, High-density polyethylene.

1. Introduction

Abandoned, lost, and discarded fishing gear (ALDFG) is one of the severe issues in ocean pollution. According to a study in Singapore, the collected ALDFG from the year 2000 to 2019 were either in whole or fragmented, with a total number more than 25,000 ALDFGs collected near Singapore ocean [1]. Among the ALDFGs, 37% were monofilament fishing lines, and 34% were fishing nets [1]. Additionally, the Food and Agriculture Organization (FAO) estimates that over 640,000 tonnes of fishing gear are lost or abandoned in the ocean every year [2]. A study in 2019 estimated that 6% of all fishing nets are lost each year across the globe [3]. These derelict fishing nets (DFN), or ghost nets, can continue to capture and kill marine animals [4]. Some marine animals can become entangled in these DFN, which can restrict their movements or result in their death. In year 2018, FAO estimated that these derelict fishing gear captures at least 650,000 marine mammals, 700,000 seabirds, and thousands of sea turtles every year [5]. These derelict fishing gears also affect the commercially valuable fish stocks [5]. World Animal Protection, a London-based non-profit organization, believes that derelict fishing gears have reduced the global fish stocks by 5 to 30 percent [5]. Figure 1 shows some of the marine animals which got entangled in these DFN.

(a) **(b)**

Fig. 1. (a) Fish and (b) crabs entangled in DFN [6].

In Malaysia, these DFN are causing harm to marine life as well as the coral reefs. There were limited studies on the negative effects of DFN on marine animals and the marine environment in Malaysia. So far, there was one report of a loggerhead turtle found entangled in a derelict fishing net near Pulau Kendi, which is an island south of Penang Island on the western coast of Peninsular Malaysia [7]. Besides that, DFN could end up entangled in the coral reefs. As these DFN settle on top of the corals, sediments start to pile up on top of the DFN, covering the corals in sediments, which could also restrict their movement [8]. Additionally, the restricted movement of the corals meant that they could not clean themselves and eventually killing them [8].

Fishing nets are made by knotting thin threads or woven in a grid-like structure to capture large quantities of fish. Around the year 9200 to 9100 BP, fishing nets are made from natural fibres [9]. With the introduction of synthetic polymers in the late 1950s, people started to use synthetic polymers as the material for fishing nets [10]. Fishing nets nowadays are usually made from plastics such as Polyamide (PA), Polyester (PES), Polyethylene (PE), and

Polypropylene (PP) [10]. These plastics are non-biodegradable and could remain in the ocean for a very long time. For some fishing nets, it could take at least 450 to 600 years, while nylon ropes may take 30 to 40 years to degrade in the ocean [11]. The difference in degradation time can be explained by several factors such as amount of UV exposure, temperature, presence of moisture and air, shape and size of the material and properties of the polymer (polymer type, molecular weight and fillers) [12]. Another issue with the decomposition of these fishing nets is that they will turn into microplastics instead of fully decomposing in the ocean [11]. Ingestion of these microplastics shall bring negative health effects on marine animals [11]. On top of that, humans could also be at risk since those marine animals that ingested microplastics could end up in the human food chain [11]. The increase of ghost nets in the ocean could be caused by humans or bad weather [13]. Some fishing nets may be discarded on purpose into the ocean, while some of the fishing nets might be lost during operation or could not be retrieved due to bad weather conditions [13].

To reduce potential harm to marine animals and the environment, DFN should be removed immediately when spotted. However, collected DFN poses yet another issue, as they are normally discarded via landfill or by incineration, both which contribute negatively to the environment. One potential method is by recycling them. Fishing nets that are made from synthetic polymers can be recycled using mechanical recycling and chemical recycling methods. Generally in the mechanical recycling process, the plastics will be reduced in size through a shredding process, sorted and cleaned, dried, and finally melt-processed into new products [14]. The disadvantage of using the mechanical recycling method is that the recycled material will produce low mechanical properties and is only applicable to thermoplastics [14]. In chemical recycling, the plastics are depolymerized to create valuable chemicals or flammable feedstocks [15]. Although this method is regarded as a promising alternative method, the treatment process requires more energy and costs more [15]. Nevertheless, the effectiveness of both recycling methods depends on their respective applications after the recycling process.

Depending on the location, the types and amount of microorganisms, exposure to ultraviolet (UV) rays, potential of hydrogen (pH) value, temperature and salinity will be different at different countries [16]. Compared to countries such as Spain and Taiwan, the UV intensity in Malaysia is higher since it is closer to the equator [17]. The higher UV intensity will increase the photodegradation rate on plastics [18]. Photodegradation is a degradation process where the polymer chains or chemical bonds are broken by sunlight to produce free radicals [19]. These free radicals react with oxygen and eventually lead to chain scission, reducing the molecular weight of the polymer [19]. Besides, the photodegradation rate of plastics will be higher when the salinity level is lower [20]. In comparison, the sea surface salinity in Malaysia and Taiwan is around 34 parts per thousand (ppt) while the sea surface salinity in Spain is around 36 ppt [21].

The most common recycling method in Malaysia is the mechanical recycling method [22]. Currently, it is difficult to find companies that recycle plastic wastes in Malaysia using the chemical recycling method. According to ENF Recycling directory lists [23], 40 companies recycle plastic wastes, including High-Density Polyethylene (HDPE), Acrylonitrile Butadiene Styrene (ABS), PP, Polyvinyl Chloride (PVC), Linear Low-Density Polyethylene (LLDPE), Polyethylene Terephthalate (PET), Polycarbonates (PC), and Low-Density Polyethylene (LDPE)

[24]. Within the list of 40 plastic recycling companies, fishing nets are not included as one of the plastic wastes they recycle. According to Reef Check Malaysia (RCM), the DFN that they collected are either incinerated or landfilled. Besides that, there were only limited studies on recycled high-density polyethylene derelict fishing nets (HDPE-DFN) in the literature in the past few years. There are no published studies on recycled DFN collected in Malaysia. Other similar studies used fishing net wastes gathered in other countries such as Basque, Taiwan, or Spain. Since the climate and ocean conditions in Malaysia are different, the conditions of the DFN may affect the mechanical and thermal properties after recycling.

The objective of this study is to understand the current condition of DFN in Malaysia by gathering information such as DFN retrieval method, disposal method, and number of DFN collected. Additionally, the material of the collected DFN was tested since they could be hard to identify through visual inspection.

2. Methodology

2.1. Survey

To gain a better understanding of the current situation of DFN in Malaysia, a survey was conducted. The first batch of survey targets organizations or individuals who have been involved in collecting DFN in Malaysia. This survey was conducted to gather information on the types and quantities of nets collected and methods used for collection. Second batch of the survey focused on Malaysian fishermen, who may have encountered DFN or may have lost their fishing nets in the ocean. This survey provides insights on the frequency of DFN encounters, as well as any disposal practices that may contribute to the issue.

2.2. Fourier transform infrared (FTIR) spectrometry

Besides conducting the survey, an FTIR test was conducted with the DFN gathered in Malaysia. This test could help identify the material of these DFN and potentially be recycled instead of being incinerated or landfilled. Samples were obtained with the help of Reef Check Malaysia. The multiple entangled DFN were separated into individual nets since there were multiple DFN entangled together. Then, three samples were taken at different parts for each DFN to identify its raw material using Fourier Transform Infrared (FTIR) Spectrometry. Before testing, the test samples were cleaned to remove contaminants and dried. The FTIR test was conducted under a wavenumber of 4000 cm^{-1} to 450 cm^{-1} with a fixed scanning resolution of 4 cm^{-1}, using Attenuated Total Reflectance (ATR) and 50 scans per sample [25].

3. Results and Discussion Survey findings

From the responses gathered from the DFN collectors in Malaysia, they have provided information such as the amount of DFN collected every year, DFN retrieval method, type of fishing net retrieved, and the material of the DFN. Table 1 shows the responses given by the DFN collectors while Table 2 shows the amount of derelict fishing nets collected every year by the DFN collectors.

Table 1. DFN collectors survey response.

Questions	DFN Collectors

	Marine Research Foundation	Tengah Island Conservation	Reef Check Malaysia (Kampung Tekek)	Department of Fisheries Malaysia	Sustainability Solutions	Reef Check Malaysia
1. How long have you been collecting derelict nets / ghost nets?	- 3 to 4 years	- 3 to 4 years	- More than 7 years	- 3 to 4 years	- 1 to 2 years	- 3 to 4 years
2. How do you collect derelict nets / ghost nets?	- Diving - Beach cleanups	- Diving - Beach cleanups	- Diving - Beach cleanups	- Diving	- Beach cleanups	- Diving - Beach cleanups
3. Do you know the type of fishing nets do you typically collect?	- I do not know - Drift nets - Trawl nets - Cast nets - Hooks and lines	- Gill nets - Drift nets - Hooks and lines	- I do not know - Gill nets - Drift nets - Trawl nets - Hooks and lines	- I do not know	- Gill nets - Drift nets - Trawl nets - Hooks and lines - Dragon trap	- Gill nets - Drift nets - Trawl nets - Cast nets - Seine nets
4. Do you know the material of the collected derelict nets / ghost nets?	- Nylon	- I do not know	- I do not know - PP - Nylon	- Nylon	- I do not know	- I do not know

Table 2. Amount of DFN collected every year in Malaysia.

Year	Amount of DFN collected (kg)						
	Marine Research Foundation	Tengah Island Conservation	Reef Check Malaysia (Kampung Tekek)	Department of Fisheries Malaysia	Sustainability Solutions	Reef Check Malaysia	Total
2017	-	-	1330	-	-	-	1330
2018	-	3351	2120	-	-	-	5471
2019	250	7213	2000	1450	-	100	11013
2020	-	673	2780	2780	100	-	6333
2021	120	642	4650	-	-	80 - Johor	5492
2022	80	2139	7268	-	-	100 - Johor	9587
2023	-	-	4000 (till August	-	20 (till September)	250 (till September) - Pulau Redang	4270

As shown in Table 1, Sustainable Solutions has been gathering DFN for 1 to 2 years through beach cleanups. Other organizations such as Marine Research Foundation, Tengah Island Conservation, and Reef Check Malaysia have been collecting DFN for around 3 to 4 years while Reef Check Malaysia in Pulau Tioman has been collecting DFN for more than 7 years. The retrieval method used by these DFN collectors were either diving or beach cleanups. The types of fishing nets retrieved were gill nets, drift nets, and trawl nets. Besides that, seine nets, cast nets, hooks and lines were retrieved as well while some fishing nets type cannot be

identified by the DFN collectors. As for the material of the DFN, most of them cannot be identified. Among those that have been identified, they were made from synthetic polymers such as nylon and polypropylene.

In the past few years, over 1000 kg of discarded fishing nets (DFN) were collected starting in 2017. In 2017, only Reef Check Malaysia was active, and they collected 1330 kg of DFN. The DFN collection increased to more than 5000 kg in 2018 and 11000 kg in 2019. However, in 2020 and 2021, there was a decrease, with only 6333 kg and 5492 kg of DFN collected, possibly due to the COVID-19 pandemic that began in January 2020 [26]. The Movement Control Order (MCO) in Malaysia restricted citizen movements to within 10 km of their homes and limited gatherings, which might have contributed to the decline [26]. In 2022, the DFN collection increased to more than 9000 kg as some restrictions were lifted [27]. A survey is ongoing with Malaysian fishermen to understand how they dispose of old fishing nets, the materials, and types of nets they use daily, and their encounters with abandoned fishing nets. This survey is still in progress.

3.2. Material of DFN

Besides conducting the survey with DFN collectors and fishermen in Malaysia, DFN from Malaysia were gathered for further testing. From the DFN obtained by Reef Check Malaysia, FTIR analysis was carried out to determine the material. The results are shown in Figs. 2 and 3.

According to Figs. 2 and 3, all samples showed similar results and peak values which could indicate that the samples could be made from the same type of material. By comparing the FTIR results with graphs for known materials, the material used to make these DFN were identified to be Polyethylene. Figure 4 shows the FTIR result of a High-Density Polyethylene material.

By comparing the FTIR results from Figs. 2 and 4, the peaks are close to the wavenumber of 2919 cm^{-1}, 2850 cm^{-1}, 1472 cm^{-1}, and 720 cm^{-1}. On top of that, Fig. 3 shows split peaks at around 1466 cm^{-1} (1472 cm^{-1} and 1462 cm^{-1}) and 725 cm^{-1} (731 cm^{-1} and 717 cm^{-1}). These split peaks are a characteristic of HDPE due to the lack of side chains which allowed the methylene chains to get close enough to orient and crystalize [28]. As for the peaks formed around wavenumber 1050 cm^{-1}, they are related to a C-O stretching vibration caused by oxidation [29]. For the peak formed around wavenumber 1650 cm^{-1}, oxidative process of -CH2 occurred which led to formation of carboxylic groups on the degraded plastic [29]. After comparing results in Figs. 2 and 3 with the results shown in Fig. 4, the material of the DFN received from Reef Check Malaysia was confirmed to be made from High-Density Polyethylene (HDPE). Since the material of the DFN has been identified, further studies can be done. For example, these DFN can be sorted according to their material type, recycled and tested for their mechanical and thermal properties.

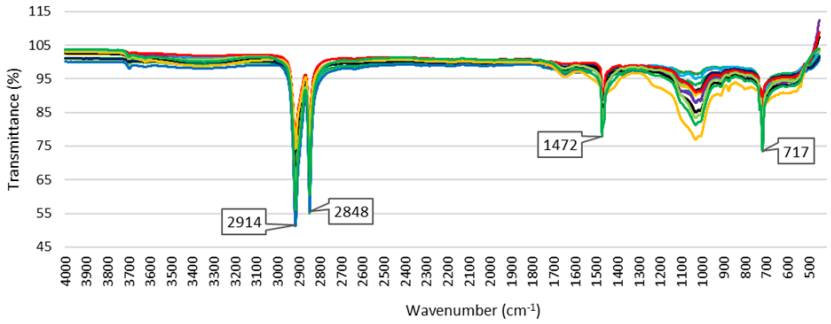

Fig. 2. FTIR results of DFN 1 to 5 under wavenumber 4000 cm^{-1} to 450 cm^{-1}.

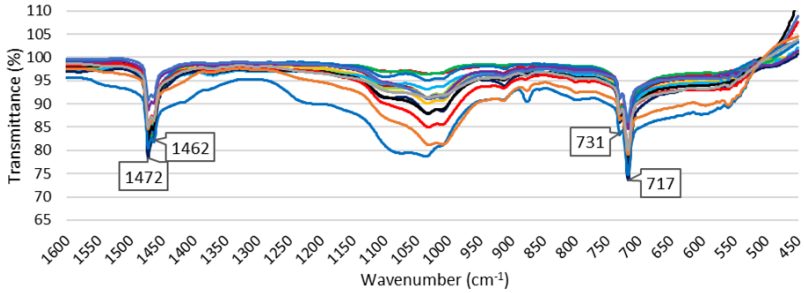

Fig. 3. FTIR results of DFN 1 to 5 under wavenumber 1600 cm^{-1} to 450 cm^{-1}.

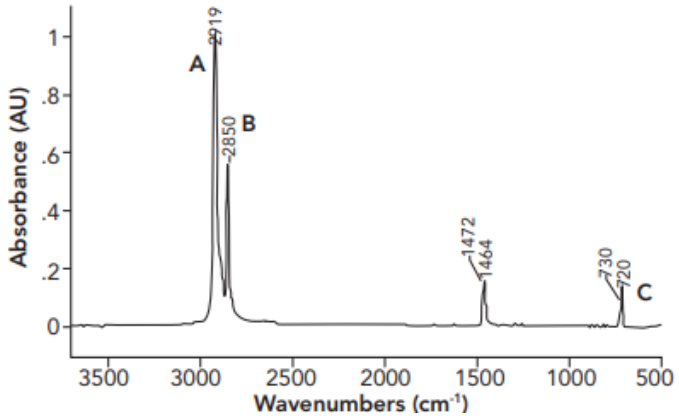

Fig. 4. FTIR results of high-density polyethylene [28].

4. Conclusions and Future Work

In summary, the information provided by the DFN collectors from the survey showed that there was at least 1000 kg of DFN collected in Malaysia every year. All respondents mentioned that they have been collecting these DFN for at least one year. The type of DFN retrieved were mostly trawl nets, drift nets, and gill nets,

while the collectors cannot identify the material of DFN. As the collectors cannot identify the materials of the collected DFN, it makes the process of recycling even more difficult. According to the FTIR results from Reef Check Malaysia samples, it showed similar peaks when compared to the FTIR result of HDPE. Similar peaks can be seen at around wavenumber of 2919 cm^{-1}, 2850 cm^{-1}, 1472 cm^{-1}, and 720 cm^{-1}. Other than that, there were also peaks around wavenumber of 1650 cm^{-1} and 1050 cm^{-1} due to degradation.

For future work, the DFN collected by Reef Check Malaysia will be mechanically recycled. Differential Scanning Calorimetry (DSC) will be used to verify the melting temperature of the DFN and to reconfirm the material. Then, the HDPE-DFN will be injection moulded and tested for their mechanical and thermal properties after recycling. The mechanical property tests include tensile test, flexural test, and impact test. Thermogravimetric Analysis (TGA) and Differential Scanning Calorimetry (DSC) will be conducted to identify the thermal degradation temperature, crystallization curve, and melting curve of the recycled DFN. Then, the mechanical and thermal properties of the recycled samples will be compared to other existing studies.

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Abbreviations

ABS	Acrylonitrile Butadiene Styrene
ALDFG	Abandoned, Lost, or Discarded Fishing Gear
ATR	Attenuated Total Reflectance
BP	Before Period
DFN	International Standard Atmosphere
FTIR	Fourier Transform Infrared
HDPE	High-Density Polyethylene
LDPE	Low-Density Polyethylene
LLDPE	Linear Low-Density Polyethylene
PA	Polyamide
PC	Polycarbonate
PE	Polyethylene
PES	Polyester
PET	Polyethylene Terephthalate
pH	Potential of hydrogen
PP	Polypropylene
PVC	Polyvinyl Chloride
RFig	Reef Check Malaysia
UV	Ultraviolet

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