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A Review on Impact of Environmental Conditions on Fishing Net Mechanical Properties

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Abstract: Fishing nets can alter the living and non-living environment whereby the target and other related resources live. In addition to selecting the right material within a particular part of the tool, the fisherman must understand the material properties, including their strength, elasticity, foldability, density, and various other properties that must be measured on each other. The fisherman should also ensure that the fishing net also has a high resistance to weathering. This review of the previous research aims to determine the mechanical properties of synthetic fiber nets under exposure to environmental conditions and artificial conditions such as UV light, seawater, xenon arc lamp, and under colored nets. The fishing net surface changes have been observed to determine the effect before and after exposure to environmental conditions. As a consequence of breaking strength, it can be inferred that sunlight is the most abrasive condition that will degrade the fishing net. These reviews of several types of research are expected to help fishing net manufacturers develop high-quality fishing nets that can last longer under weather conditions. In particular, in terms of increasing the life span of fishing net, regular protection and preservation measures are required that reduce the effective and sustainable use of fishing net at different seasons.

Keywords: Fishing Net, Environmental Conditions, Breaking Strength

1. Introduction

In recent years, there is always an increasing number of people every day that has made the efficient production of food from the sea more significant. Fish are an essential source of protein, especially in countries such as Ireland, Switzerland, and Japan, where the land is hilly, and this is not easy to do agricultural. Fishing has been classified as one of the world's most life-threatening professions [1]. As used in Malaysia, the fisheries sector plays a vital role as a provider to a source of protein. The fishing industry consists of two major parts that are fishing and aquaculture for marine catches. Marine-capture fishing has been classified into two main categories, namely inshore fishing, and deep-sea fishing. The

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aquaculture industry only accounts for 10.00 % of total fish production, but this sector is potentially the source for future fish demand [1].

Modern fishing has evolved into three major technologies, including mechanization, fish finding gear, and synthetic fibers [2]. The primary raw material that was used to make a fishing net in Malaysia was synthetic nylon fiber. Weather-deteriorating behavior usually happens when the net is in use. Materials typically exposed to different weather types are most often degraded by sun exposure, thermal effects, and moisture. Polymers like nylon and acrylics are often damaged by water through hydrolysis. A plastic loses strength caused by physical occurrences in physical deterioration. Degradation rates at sea differ from those on land. High humidity can speed up the degradation rates of several plastic classes. The exposure of materials to environmental conditions causes many material failures.

During fishing, the UV radiation, water, and salts influence the fishing gear and the polymer chains, degrade to decrease the molecular mass, and start releasing various chemical species. Besides, a process known as ghost fishing starts when the abandoned gear enters the seabed and begins to catch and kill ocean life [3]. The fishing net made with nylon or other synthetic fibers mostly are non-biodegradable and utterly entangled with the ecosystem [4]. Therefore, exposing different environmental conditions on the fishing gears affected its strength, where many fishing nets were found floating on seawater and entangled the ecosystem. Many companies involved in recycling the fishing gear, such as Adidas, have produced a shoe made from ocean plastics and swimsuits made from ghost nets.

This research aims to review the fishing net's mechanical properties, including the breaking strength and the tensile strength of the netting twine under exposure to environmental conditions. Also, based on the previous research, the morphology of the fishing net that has been observed after the exposure to the environmental condition will be reviewed.

2. Methodology

The methodology used for reviewing journals based on criteria and properties was being clarified and explained in this section. At the first stage of the research, all possible keywords used in the report were identified. Search engines such as ScienceDirect and Google Scholar have been used to identify published academic journals with similar ideas. The selection of the following words was used in the first stage of the analysis. The publications were retrieved at this stage of the research. The findings were then filtered by 'article category' such as research papers and analysis articles. The findings of years were filtered between 2000 to 2020 to be screened for the next step. For the title and abstract, the papers have been thoroughly investigated. For example, the selected article must rely on the chosen properties of mechanical properties. The articles were reviewed in-depth at the third stage of the study, leaving nine documents for another step. The next phase of the review involved reading the following content of all the articles collected. Then, the overview of the critical subject of the research, the methodology used, and the main contributors reviewed in the papers.

3. Results and Discussion

The outcome and discussion of the literature review process will be in this chapter. The results and discussion concentrate on the similarities and suitability of studies.

3.1 Breaking strength of fishing net expose to environmental conditions

The efficiency of a material and its longevity are two key factors affecting the material choice for fishing nets in various environmental conditions. So, to a very great extent, the quality of a fishing gear depends on the materials used for its construction.

3.1.1 Exposure to UV radiation

The breaking strength of the material demonstrates the strength of fishing nets to withstand the strain. It depends on polymer characteristics, the degree of twisting, the type of yarn, and the thickness of the material [5]. Based on the method [6], the materials were exposed to the sunlight for three months. The samples from the test material have been removed for measuring the change in breaking strength and weight loss after 90 days of exposure. The result shows that the monofilament yarn and multifilament twine's initial breaking strength were 24.76 N and 26.7728 N, respectively. The monofilament twine can break in the 80.00-90.00 % range of breaking strength depending on the knot compare to the multifilament twine. Table 1 shows the breaking strength of materials exposed to sunlight are reduced at the end of 90 days of exposure.

Table 1: The breaking strength of monofilament yarn and multifilament twine and the initial value percentage [6]

Day	Monofilament yarn (%)	Multifilament twine (%)
0	100	100
8	89.46	90.85
15	87.23	82.68
30	84.35	74.52
45	80.42	71.01
60	77.41	65.09
90	74.23	61.52

Coating the knots is vital to avoid the net's deformation when a load or environmental conditions are imposed. However, these coatings are characterized by the ability to preserve the fishing net to which they are applied from the elements to which the nets are exposed, including sunlight and water [7]. Based on the result reviewed by [8], 40 grey colors acted as a control, 40 were coated with a film of coal tar diluted in heavy oil before use, and 40 untreated green-colored twines were used to determine whether pigmentation affected UV resistance. The mean annual temperature in this area is 28.6 ◦C, and sunshine hours are 9.7 h per day. The breaking strength resulted in Figure 1 of treated and untreated grey twines was determined to be higher than untreated green twine. Following a one-week exposure to solar irradiation, breaking strengths declined. The mean breaking strength for coal tar treated grey twines was more significant than that observed for either untreated grey twines or untreated green PA. For the following seven weeks of the trial, coal tar treated twine returned superior breaking strength characteristics than non-treated twines, irrespective of color. These results indicate that exposure of netting twines to solar irradiation increases the rate of deterioration as this pertains to breaking strength.

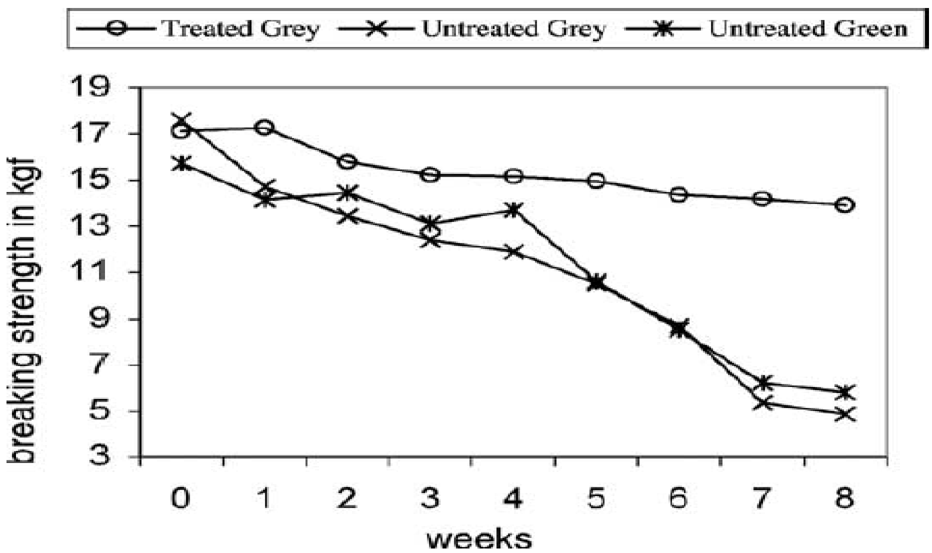

Figure 1: The mean breaking strength for the three types of twine[8]

The use of xenon arc lamp encourages alterations in the materials' properties, including the sun's UV rays, heat, and moisture, by simulating ultraviolet or visible solar radiations. Accelerated exposure testing has become extremely necessary to identify new materials and assess materials performance in a relatively short time in a real environment [9]. Xenon arc is a precise emits light lamp in a closed quartz tube used to stimulate the weathering effects when materials are exposed to sunlight. Based on the result obtained from the research [2], the Xenon arc lamp is used to conduct the test. The mesh's breaking strength (36 mm in diameter and 18 mm mesh) was performed under exposition to normal light conditions. Table 2 shows the mean value of breaking strength of the fishing net after exposure to artificial sunlight. Besides, the one-hour xenon arc lamp effect is equal to the impact of remaining under daylight for 9 hours. The data obtained from the experiments indicate that the differences among the mean levels of duration factor were not found statistically significant. Therefore, there is no difference between the mean value of the untreated sample and the mean values of the sample treated with Xenon arc lamp for different periods.

Table 2: The mean values of breaking strength of fishing net and untreated fishing net after exposure to artificial sunlight[2]

Hours	40	160	200	300
Mean	461.23	459.76	462.5	461.66
±Std. Dev	28.63828	21.74336	22.63326	21.70173

Overall the results indicate that sunlight is an important cause of damage to netting twine. The ultraviolet light has long been recognized as being responsible for most of the deterioration of netting twine. The accelerated weathering tester such as Xenon Arc Lamp has been used to simulate sunlight and the damage caused by sunlight [10]. Polyamide (PA) properties are strong, light, elastic, stretchable, high abrasion and temperature resistance. However, its drawbacks are the increased absorption of moisture and the requirement of UV stabilization [5].

3.1.2 Breaking strength under seawater

The biodegradable fishing nets are expected to degrade underwater over a certain period and lose their ghost fishing strength more quickly than conventional fishing nets. Biodegradable monofilament has begun to lessen in seawater by marine species after 24 months [11]. The strength of breakage from previous research experiments was contrasted with that of commercial nylon netting twine of the same performance and the result shown in Table 3. The result [12] reveals that the breaking strength of nylon monofilament was 58,361 $N\cdot cm^{-2}$ when dry and 47,508 $N\cdot cm^{-2}$ when wet. The strength in wet conditions reduced by 18.80 % relative to that in dry conditions.

On the other hand, the bio-degradable monofilament net had 47,508 $N\cdot cm^{-2}$ in dry condition and 47,005 $N\cdot cm^{-2}$ in wet condition, equivalent to 99.10 % of the wet nylon strength. Following the netting yarn quality, PBS would be an aliphatic polyester with high flexibility, good mechanical strength, and high crystalline strength. At the same time, the PBAT resin has the same properties as the elastomer. So, PBAT has an excellent extension coefficient and, at the same time, has low strength and low solidification rate relative to the PBS resin as a homopolymer. Using the different properties of the PBS resin and the PBAT resin, the structural strength needed for the fishing net was ensured. Simultaneously, the stability, elasticity, and impact resistance of the fishing nets were ensured (P. Kim et al., 2020).

Table 3: Bio and Nylon monofilaments breaking strength in dry and wet conditions[12]

Material (Diameter, mm)	Denier (Td)	Weight ($g\cdot m^{-1}$ ± S.D.1)	Breaking strength Dry ($N\cdot cm^{-2}$ ± S.D.)	Wet ($N\cdot cm^{-2}$ ± S.D.)

Nylon2) (Ø0.293)	690.92	0.077 ± 0.0001	58,361 ± 10.93	47,409 ± 19.28
Bio3) (Ø0.296)	783.88	0.087 ± 0.0010	47,508 ± 4.25	47,005 ±4.75

Compared to the result (S. Kim et al., 2016) in Table 4, the knotless nylon monofilament breaking strength was 59.55 kg mm^{-2} when dry and 48.38 kg mm$^{-2,}$ an estimated reduction of 19.00 % when wet. In contrast, the knotless biodegradable monofilament's breaking strength was 47.74 kg mm^{-2} when dry and 47.10 kg mm^{-2} when wet.

Table 4: The breaking strength of knotless biodegradable and nylon monofilament[11]

Material (Diameter, mm)	Denier (Td)	Weight (g·m-1 ± S.D.1)	Breaking strength Dry (N·cm^{-2} ± S.D.)	Wet (N·cm^{-2} ± S.D.)
Nylon monofilament Diameter: 0.29 mm	691.92	0.077 ± 0.0001	59,55 ± 1.12	48,38 ± 1.97
Biodegradable monofilament Diameter: 0.30 mm	803.71	0.089 ± 0.0010	47,74 ± 0.70	47,10 ±0.57

3.2 Tensile strength of the fishing net

The tensile strength test is one of the mechanical tests that was applied to the material. The tensile strength test aims to evaluate the mesh breaking strength and determine how far the mesh can elongate. It helps to assess whether the nets will continue being used or need immediate replacement.

The degradation of synthetics exposed to the atmosphere depends on several factors: the intensity of UV radiation, relative humidity, and temperature [13]. The UV radiation that stimulates the primary photochemical process seems to be the most significant factor responsible for the deterioration of polymers by weathering. Table 3.5 shows that the retained tensile strength of monofilament yarns exposed in water and atmosphere was 81.41 and 74.23 %, respectively, at the end of 90 days [14], and the tensile strength of multifilament twines exposed in water and atmosphere were 72.38 and 61.52 respectively. Tensile strength for polyamide multifilament twines of 210 × 1 × 2 was less than polyamide monofilament yarns of 0.23 mm diameter in all three. Therefore, the tensile strength of PA multifilament twines was more susceptible to degradation than monofilament yarns.

Table 5: Tensile strength of monofilament and multifilament yarn at the end of 90 days [14]

	In water (%)	Under sunlight (%)
Monofilament yarn	81.41	74.23
Multifilament yarn	72.38	61.52

The loss of resistance inside the net and the elongation of the mesh that can elongate are vital for users of fishing nets like fish farmers to evaluate after a particular operation in the sea. Thus, it will help determine whether the nets will continue to be used or need immediate replacement [15]

3.3 Net morphology after exposure to the environmental conditions

A wide range of specimen types is usually examined with the scanning electron microscope. It is possible to adapt the light microscope to examine specimens of any size, such as the fishing net sample, under dry and wet conditions.

The degradation rate was higher in higher water temperature in summer, which indicates that the biodegradation process is temperature-dependent. It is well demonstrated that although conventional nylon nets are highly resistant to degradation, they eventually lose their capability for ghost fishing, the time depending mostly on conditions of the substrate on which the derelict gear is located, current strength, frequency of storm events, and interactions with active fishing gear and vessels. Figure 3.2 shows the observation of biodegradable monofilament's surface through degradation process at six months up to 42 months [11].

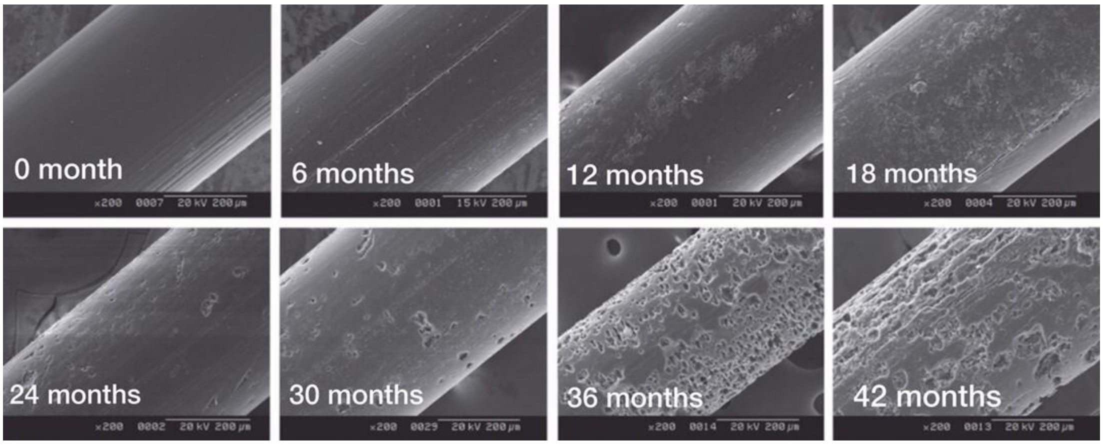

Figure 2: The observation of degradation process of biodegradable monofilament surface [11]

The degradation of biodegradable monofilament resulted from mechanical changes that occurred during the 42 months experimental period. An article [16] provides the result of Polyvinyl chloride (PVC) that degrades and leads to new surface functional groups of PVC that affect the mechanical properties and may change their interactions with contaminants microorganisms. The previous research findings indicate that PVC exposed to seawater continues to degrade at a slightly slower rate than PVC exposed to sunlight. As a result, it can be assumed that PVC particles in marine environments might degrade at a slightly slower pace than in non-marine environments[16]. Figure 3 indicates the image of surface topography of PVC samples has been amplified 5000 times using SEM.

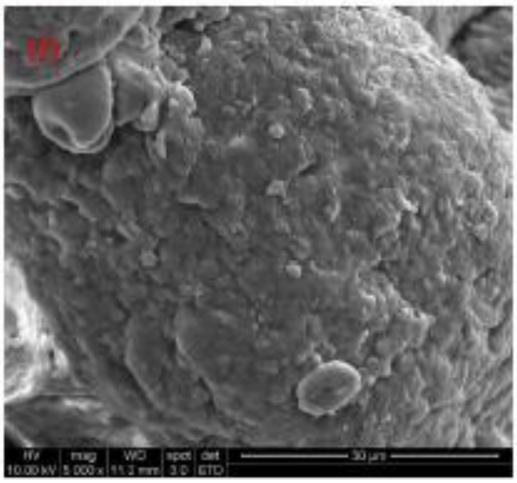

Figure 3: Image of surface topography of PVC [16]

4. Conclusion

As explained in the previous chapter, the twine made from nylon polyamide has high mechanical strength, good toughness, and high tensile strength. Still, it has several limitations in which the polyamide twine has weak resistance to light in the long period with high temperature. At the same time, when immersed in seawater, the fishing net may absorb water and swell. The strength properties of fishing net in different environmental conditions may be varied.

This research reviewed focuses on the environmental conditions that impact the mesh's mechanical properties and knotted fishing nets structures. Exposing the twine under UV light, seawater, and soil will be affected by the tensile properties and breaking strength. The twines exposed to the environmental conditions will also change their diameter, and the meshes tend to shrink or pull-out.

Other than that, from the research paper, the surfaces of the fishing net were observed based on the publication. The biodegradable net surface structure showed that the degradation occurred after two years of exposing the net to seawater. The surface of the biodegradable net abrasively changed after two years.

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