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Determination of Mesh Breaking Strength of Polyamide Fishing Nets Under the Exposure of Different Heavy Metal Concentrations and Temperature

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ABSTRACT

Pollutants and other external factors effect the strength and service life of fishing nets. The effects of some pollutants such as heavy metals and temperature on the mesh breaking strength of knotless polyamide (PA) fishing nets were determined in this study. The PA net samples were subjected to heavy metal solutions containing Cd (Cadmium), Cu (Copper), Ni (Nickel), Hg (Mercury), Zn (Zinc), Cr (Chromium) and Pb (Lead) for 14 days at 99 °C in metal and glass containers. Also, the samples were hold on metal and glass surfaces and suspended in the air at 130 °C and 175 °C for the periods of 30 minute, 1 and 2 hours. The order of breaking strenght values of heavy metal treated samples in metal containers was found Ni> Cd>Pb> Zn> Hg>Cu> Cr, respectively, whereas the order of samples was Cr>Hg>Cu>Pb>Zn> Cd> Ni for glass containers. Regarding to the test conditions and the temperature, the breaking strenght values of samples treated with 130 °C were found significantly high ($P<0.05$) compared with those hold at 175 °C for both metal and glass surfaces and air suspended groups in all durations.

Keywords: Fishing net; Polyamide; Heavy metals; Temperature; Mesh breaking strength

Farklı Ağır Metal Konsantrasyonlarına ve Sıcaklığa Maruz Bırakılan Poliamid Balık Ağlarında Ağ Gözü Kopma Kuvvetinin Belirlenmesi

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ÖZET

Çevre kirliliğine yol açan maddeler ve diğer dış faktörler, balık ağlarının dayanıklılığını ve kullanma ömrünü etkilemektedir. Bu çalışmada, ağır metaller gibi bazı kirleticilerin ve sıcaklığın, düğümsüz poliamid (PA) balık ağlarında ağ gözü kopma kuvvetine etkileri belirlenmiştir. PA ağ örnekleri,14 gün boyunca 99 °C'de metal ve cam konteynırlar içinde Cd (Kadmiyum), Cu (Bakır), Ni (Nikel), Hg (Civa), Zn (Çinko), Cr (Krom) ve Pb (Kurşun) içeren ağır metal solüsyonlarına maruz bırakılmıştır. Ayrıca, örnekler 30 dakika, 1 ve 2 saat süresince, 130 °C ve 175 °C'de metal ve cam yüzeyler ile havada asılı olarak tutulmuştur. Metal konteynır içinde ağır metale maruz bırakılan örneklerde ağ gözü kopma kuvveti değerleri sırasıyla Ni>Cd >Pb > Zn> Hg> Cu> Cr olarak bulunurken, cam konteynır içindeki örnek değerlerinin sırası Cr> Hg> Cu> Pb> Zn>Cd> Ni olarak tespit edilmiştir. Test koşulları ve sıcaklık ile ilişkili olarak, metal ve cam yüzeyler ile havada asılı tutulan gruplarda tüm zaman periyotlarında 130 °C'e maruz bırakılmış örneklerin kopma kuvvetinin 175 °C'deki örneklere göre yüksek ($P<0.05$) olduğu bulunmuştur.

Anahtar Kelimeler: Balık ağları; Poliamid; Ağır metal; Sıcaklık; Ağ gözü kopma kuvveti

1. Introduction

Fisheries have developed continuously over the centuries, utilising improved and larger ships, more sophisticated fishing equipment and catch preservation techniques. Modern fishing has developed through three main technological revolutions such as development of mechanization, fish finding equipments and netting material (FAO 2005; Ramos 1999; Sainsbury 1996). The netting materials are usually produced of knitted bundles of multifilaments (knotless netting) or twines of twisted multifilament bundles that are connected by knots (knotted netting) (Moe et al 2007).

Most net cages are made of square mesh knotless Polyamide (PA) netting and Polyester (PES), Polyethylene (PE), Polypropylene (PP) and Polyvinyl alcohol (PVAA) ropes (Ramos 1999; Klust 1982; Moe et al 2007). PA continuous filament netting yarns have the highest wet knot breaking strength, followed by PP, PE and PES, while PVAA, PVC (Polyvinyl chloride) and PVDC (Polyvinylidene chloride) are too poor in this respect to be eligible for bottom trawls (Klust 1982).

Deterioration of a polymer is defined as embrittlement and/or loss of physical integrity of a polymer regardless of the mechanism which brings about these changes and degradation is deterioration which results from a chemical process. Materials are degraded most often by sunlight, thermal effects and moisture. Also, other factors such as air contaminants, oxygen and salt can contribute to degradation. Rate of degradation at sea is different from that on land. High humidity is known to accelerate the rates of degradation of several classes of plastics. This may be brought about by the plasticizing action of small quantities of sorbed water leading to increased accessibility of the matrix to atmospheric oxygen or by the leaching out of stabilizing additives from the formulation (Andrady 1990). The higher temperatures induced the degradation and may even be high enough to induce significant thermooxidative degradation. Plastics at sea will not suffer from such temperature build up and may consequently undergo slower oxidative degradation and photodegradation (Boxhammer 1999; Boxhammer & Scott 1999; Summers & Rabinovitch 1999; Masters & Bond 1999; Wypych & Faulkner 1999).

The effects of weather on the properties of materials have a considerable technical and commercial importance. Researchs regarding to the properties and the factors that influence the fishing net materials are very limited and have not been decently analysed (Sala et al 2004; Al-Qufi et al 2004), therefore we aimed to test the mesh breaking strenght of PA fishing nets under simulated environmental conditions with laboratory instrumentation under more controlled and accelerated conditions as compared to outdoors exposure in this study. The results of this study can be used for method validation activities and in practice, by the users of fishing nets.

2. Materials and Methods

2.1. Preparation of PA net samples

The 36/18 (Netting yarn 3.6 mm in diameter and 18 mm mesh) knotless multifilament PA 6.6 fishing nets were used in the experiments. The material was imported by “Delta” from “Remer S.r.l.” in Italy. The fishing nets were split carefully with scissors without any damage to the meshes.Samples were mixed except the ones used in the test of suspended in contact with air.

2.2. Preparation of heavy metal concentrations

The concentrations of heavy metals adjusted to 10 fold higher in comparison with the general quality criteria of sea water (Anonymous 2010) to imitate the pollution effect in the aquatic environments. The concentrations of heavy metals are as follows; Cr (1 mg L^{-1}), Cd (0.1 mg L^{-1}), Cu (0.1 mg L^{-1}), Hg (0.04 mg L^{-1}), Ni (1 mg L^{-1}), Pb (1 mg L^{-1}) and Zn (011 mg L^{-1}). The solutions were prepared by the TSI Ankara Chemistry and Materials Laboratory.

2.3. Metal and glass containers

The metal containers were stainless steel which conforms to EN 10088 Gr 1.4401 with 16.5-18.5% chromium and 10.5-13.5% nickel content. ISOLAB/Germany branded NS 29/32 model 250 mL borosilicate glass conical flasks and ISOLAB/Germany branded 1000 mL borosilicate glass beakers were used as glass containers.

2.4. Metal and glass surfaces

The aniodized aluminium bottom of a NÜVE/Turkey branded FN 400 model drying oven is used for holding on metal surface and tempered heat-resistant glass petri dishes were used for holding on glass surface.

2.5. Experimental design

The experiments were carried out in a conditioning room of TSI Denizli Regional Directorate Textile Laboratories which was accredited by TÜRKAK. It is equipped with a breaking strength device at a temperature of 20$\pm$2 ^{o}C and a relative humidity of 65$\pm$2%, that are specified in the TS EN ISO 139 Standard (TSI 2006).The conditions of the room are maintained and recorded 24 hours a day through the tests.The results were obtained from three replicates by calculating the breaking strength of individual meshes within a certain area of netting with minimum 10 mesh measurements.

Temperatures applied to samples in the experiments were chosen by taking into consideration testing temperatures which are elaborated in majority of research works. The literature concerning experiments and tests of synthetic textile fibres set varying to the temperatures of viscon samples in dry conditions as 130 °C and 170 °C (Bulut & Akbulut 2012), and hot water shrinkage of all kinds of synthetic fibres as 95 °C (Swicofil 2013). In this study, simulated values of these temperatures were applied on samples by taking account of device deviation values in calibration reports.

2.6. Measurement of dry/wet mesh breaking strength

The principle of the measurement of dry mesh breaking strenght is extending a mesh until it ruptures under the applied load (TSI 2004; British Col. Ministry of Agric. Food and Fisheries 2002). For testing the wet mesh breaking strength, netting material has been immersed in the testing liquid and surplus of the liquid has been removed at the end of test period. The tests were carried out an INSTRON-England branded 4465 model breaking and tearing strength test device (serial number: UK-225) having a constant elongation rate, in accordance with TS 6246 EN ISO 1806/2004 standard and mesh breaking strength method. As required by the standard, the values obtained from the testing of meshes that do not break at the knots were not included in the calculation.

2.7. Holding the samples in a metal container

These tests were performed with a Washing and Dry Cleaning Fastness (Gyrowash) device (James H. Heal Co. Ltd.-England). The samples were placed into the metal containers of the device at least to the half length and the containers were filled with solutions containing heavy metals. The containers were placed in the device containing distilled water at 99 °C (Swicofil 2013) and subjected to testing for 14 days.

2.8. Holding the samples in a glass container

The samples were soaked in a heavy metal solutions and placed in 250 ml glass conical flasks filled with 250 ml of heavy metal solution and closed with its cap. The container was positioned at the bottom of the conditioning cabinet set (WEISS/Germany SB 11^{300} model) at 99 °C (Swicofil, 2013) and subjected to testing for 14 days.

2.9. Holding the samples on a metal and glass surface

For metal surface, the samples were placed into the aluminium bottom of a drying oven (NÜVE/Turkey FN 400 model) and for the glass surface, they were placed on glass petri dishes and subjected to testing at 130 ºC and 175 ºC for 30 min and 1 and 2 hours. At the end of the test period, the samples were kept in the conditioning room for a period of at least one day before testing.

2.10. Holding the suspended samples in contact with hot air

The samples were suspended on polyester threads which are strung in a drying oven and tested at 130 ºC and 175 ºC for 30 min, 1 and 2 hours. At the end of the test period, the samples were kept in the conditioning room for a period of at least one day before testing.

2.11. Statistics

Data presented here are means±standard deviation (SD) of three replicates. One way analysis of variance (ANOVA) and Independent samples T-Test was applied using statistical software SPSS 11.5 (SPSS 2003). For comparison of the means DUNCAN multiple comparison test was used (Kesici & Kocabaş 2007).

3. Results and Discussion

The data obtained from the experiments are given in the Table 1 and 2. The mean breaking strength of untreated 36/18 samples was found 461.45 N±22.90. The mesh breaking strength of 36/18 fishing net samples in metal and glass containers after exposure to heavy metal solutions at 99 °C for 14 days, show that the samples treated in metal containers lost their strength much more than those of samples treated in glass containers.

For the samples treated with metal solutions in metal containers, the order of breaking strength values is Ni>Cd>Pb>Zn>Hg>Cu>Cr whereas the order was Cr>Hg>Cu>Pb>Zn>Cd>Ni in glass containers. Contrary to the results of the metal container, Ni was the weakest abrasive metal for glass containers in the experiment (Table 1). Furthermore, no significant differences were observed with regard to Cd, Cu, Ni, Hg, Zn and Pb treated samples both for metal and glass containers, however, a remarkable difference was found in Cr treated samples between groups ($P<0.05$).

Considering the present data, we can conclude that metal containers react earlier than glass containers in the presence of heavy metal solutions. Data obtained from the 36/18 fishing net samples held on metal and glass surfaces and suspended in the air at 130 °C and 175 °C for the periods of 30 min.,1 and 2 hours, demonstrated that the breaking strength values of samples remained unchanged at 130 °C ($P>0.05$). Nevertheless, a significant increment was observed on the breaking strength values of samples at 175 °C ($P<0.05$) (Table 2). The order of loss of breaking strength values at 175 °C was as follows; Contact with metal surface> Contact with glass surface> Suspension in the air. The mesh breaking strength values were reduced according to the incremental levels of temperature and the lowest values were determined at 175 °C for 2 h exposure both all treatment groups ($P<0.05$). The test conditions in laboratories such as materials of containers, temperature, duration and chemicals have a great impact on the results of this study. In agreement with previous researchs (Sala et al 2004), for more certain outcomes the performance of net material has to be investigated elaborately. For fishing nets increase in temperature and being in contact with metal materials in wet conditions results in accelaration of the loss of strength with the progression of time in laboratory conditions in this study. In this sense, as corroborating our results, Andrady (1990) stated that high humidity can accelerate the rate of thermooxydative degradation especially at elevated temperatures.

4. Conclusions

Our experimental results were in agreement with previous research findings that emphasized on the pollutants as heavy metals and demonstrated that they can substantially decrease the strength of fishing nets and affect the costs, productivity and effectiveness of fishing operations. Furthermore, as an evaluation of temperature, a critical factor on the breaking strength of netting samples, this research exhibited that higher temperatures comparison to lower levels can be more destructive to netting material.It is advisable that fishing nets should not be stored in metal containers and on metal surfaces and should be aerated and dried following their usage.

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Table 1- The breaking strength (Newton, N) values of 36/18 fishing net samples exposured to heavy metals by holding in metal and glass containers at 99 °C for 14 days (Mean value ± Standard deviation, n=15)

Çizelge 1- Metal ve cam konteynırlarda 14 gün süresince 99 °C da ağır metallere maruz bırakılan 36/18 balık ağı örneklerine ait kopma kuvveti değerleri (Ortalama değer ± Standart sapma, n=15)

Heavy metals	*Test method**	
	GC	*MC*
Cd	459.00±25.93	458.21±24.71
Cu	466.10±29.88	444.44±35.22
Ni	455.70±33.42	460.59±23.79
Hg	466.94±22.48	448.86±24.52
Zn	461.69±22.95	451.00±30.96
Cr	$468.90±19.95^{a***}$	$437.47±17.52^{b}$
Pb	464.63±19.20	454.49±34.02
DS**	$418.66±43.03^{a***}$	$336.38±24.96^{b}$

* GC, glass container; MC, metal container; ** DS, distilled water; *** means in the same row with different superscripts significantly differ (*P*<0.05)

Table 2- The breaking strength (Newton, N) of 36/18 fishing net samples holding on metal and glass surfaces and suspending in the air at 130 °C, 175 °C for 30 minute, 1 and 2 h (Mean value±Standard deviation, n=15)

Çizelge 2- Metal ve cam yüzeyler ile havada 130 °C ve 175 °C de 30 dakika, 1 ve 2 saat süre ile asılı tutulan 36/18 balık ağı örneklerine ait kopma kuvveti değerleri (Ortalama değer ± Standart sapma, n=15)

Duration	*Temperature (°C)*	*Test method**		
		SA	*GS*	*MS*
30 min	130	$460.86±26.30^{aAX}$	$461.54±28.71^{aAX}$	$451.50±31.38^{aAX}$
	175	$401.06±26.15^{aAX}$	$348.32±30.45^{bAY}$	$306.56±38.24^{cAY}$
1 h	130	$460.86±26.30^{aAX}$	$463.15±25.76^{aAX}$	$456.39±20.92^{aAX}$
	175	$400.34±20.72^{aAY}$	$340.95±33.41^{bAY}$	$274.00±75.24^{cAY}$
2 h	130	$451.60±30.87^{aAX}$	$451.53±36.07^{aAX}$	$451.50±31.38^{aAX}$
	175	$359.79±70.52^{aBY}$	$279.33±76.24^{bBY}$	$161.64±84.04^{cBY}$

* SA, suspended in air; GS, glass surface; MS, metal surface; ** Means in the same row with different superscripts significantly differ (*P*<0.05). Means in the same row and temperature at different duration with superscripts A and B significantly differ (*P*<0.05). Means in the same column and duration at different temperature with superscripts X and Y significantly differ (*P*<0.05)

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