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THE COMBINED EFFECT OF UV-RADIATION AND SOIL MICROORGANISMS ON THE BIODEGRADABILITY OF POLYETHYLENE PACKAGE FILM WITH STARCH ADDITIVE

Abstract

Studies were carried out on the degradation of polyethylene package film with 5% of starch (MALEN E FABS 23 DO 22), which was exposed to UV rays (low pressure mercury lamps Philips UV-A TL/05, 15 W power, emission maximum 365 nm) and soil microorganisms. Film of the 0,04–0,1 mm thickness film was exposed to UV radiation for 60 h, 120 h, 180 h, 240 h, 300 h and 800 h. The exposed film was stripped up into 150 mm × 15 mm pieces and underwent the soil burial test for 24 weeks in the temp. of 28–30°C and relative humidity of 20–30%. The degradation was estimated based on the tensile strength. The impact of the UV-radiation exposure time and soil microorganisms on the mechanical properties of the polyethylene film with starch were analysed by the regression models. The 3-rd order polynomial model was fitted to empirical data. The tensile strength was turned out to be useful measure of the mechanical changes in the polyethylene film.

Introduction

Polyethylene is a polymer which, beside polyvinyl chloride, has the highest share in the production of plastics in the world [4] and at the same time is one of the most difficult degradable polymer in the environment [1]. It is attempted to enhance the degradability of polyethylene waste e.g. by the addition of a natural polymer like starch as a filling material [3]. The use of starch is based on an assumption that it is easily biodegradable giving rise to a decrease in weight and making the structure of the remaining part of the polymer looser. Such a porous material can be more easily saturated with oxygen and colonised by microorganisms which enhances its biodegradability.

The degradation of polymers can occur due to the process of photodegradation [5]. It takes place by the action solar radiation, especially the ultraviolet rays, which damage the polymers. In the process of photodegradation, three stages can be distinguished, namely:

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destruction (the abstraction of hydrogen atoms from the chain), cross-linking (the formation of transverse bondings) and degradation (the cracking of main chains). It is believed to be the initial path for the degradation of plastics in the environment.

The aim of this work was the estimation of the degree of the degradation of a film of polyethylene with added starch exposed to UV-radiation and the action of soil microflora.

Material and methods

Material

The studies were carried out on LDPE FGNX 18-D O22 samples with the addition of a biodegradable concentrate BIO-50 (in the amount yielding 5% of potato starch in the film), manufactured in Chemical Works in Kędzierzyn-Koźle. The thickness of the film varied between 0.04 and 0.1 mm.

UV Irradiation

UV irradation was based on ASTM D5208-91 [2]. Superactinic low pressure mercury lamps Philips UV-A TL/05 (15 W power, UV-A radiation power 2.1 W, 300–500 nm spectrum range, emission maximum – 365 nm) were employed for the irradiation. Four lamps were mounted in equal distances on a wooden frame of 440 mm × 320 mm dimensions. A band of film stretched parallel to the plane of the lamps was irradiated from a distance of 140 mm. The films were irradiated in daily cycles: 12 h/12 h (lamps switched on 9 a.m. to 9 p.m., lamps switched off 9 p.m. to 9 a.m.). The total time of the irradiation of individual film samples was 60 h, 120 h, 180 h, 240 h, 300 h and 800 h. The irradiated film samples were cut along the band into strips of 150 mm × 15 mm dimensions (5 pieces for each measurement).

Soil burial test

The films irradiated previously by the UV lamp were incubated in containers with microbiologically active soil containing: peat, river sand, compost earth and manure, all in equal parts. The incubation of the film in the soil was carried out at the temperature of 28–30°C and relative humidity of 20–30% for 24 weeks.

The films subjected to the combined effect of the UV irradiation and the soil agents were compared with (1) sufficiently long UV irradiated films but not subjected to the soil burial test, (2) brand new films (subjected neither to irradiation nor to the soil burial test).

Determination of strength characteristics

The tensile strength was determined according to the standart PN-68/C-89034 [6] and using a device for the study of the mechanical strength – Zwick 1445. The initial distance of jaws was 50 mm and the testing rate 50 mm/min.

The tensile strength was calculated using the formula:

$$N = F \times P^{-1} \; [N \times m^{-1}],$$

where: F is the maximum measured force [N]
P is the sample cross section area [m^2]
The obtained results were subjected to variance analysis.

Results

The impact of the UV radiation exposure time and soil microorganisms on the mechanical properties of the polyethylene film with starch is analysed by the regression models. The tensile strength has turned out the useful measure of the mechanical changes in the polyethylene film. The theory of the photodegradation predicts the three-phase of the process [5]. The first phase, *the destruction*, leads to the lowering the tensile strength of the polyethylene film. In the next phase, *the cross-linking*, the tensile strength increases. In the last phase, *the degradation*, the UV-radiation decreases the tensile strength again. It follows that the polynomial of the 3-rd order seems to be the best model for the tensile strength. The results of the estimation of the model are presented in table 1.

Table 1

The results of the estimation of the 3-rd order polynomial for tensile strength of the polyethylene with starch (Variable: time of the UV radiation [hours])

Variable	Estimate	Standard error	Student t	p-value
Time	-.016804	.007324	-2.295	.01429
$Time^2$	$5.87284*10^{-5}$	$3.2562*10^{-5}$	1.804	.04096
$Time^3$	$-5.11442*10^{-8}$	$3.0236*10^{-8}$	-1.692	.06004
Intercept	7.591848	.394814	19.229	.00000

$R^2 = 0.30590$

The impact of the UV-radiation on the tensile strength is shown in fig.1.

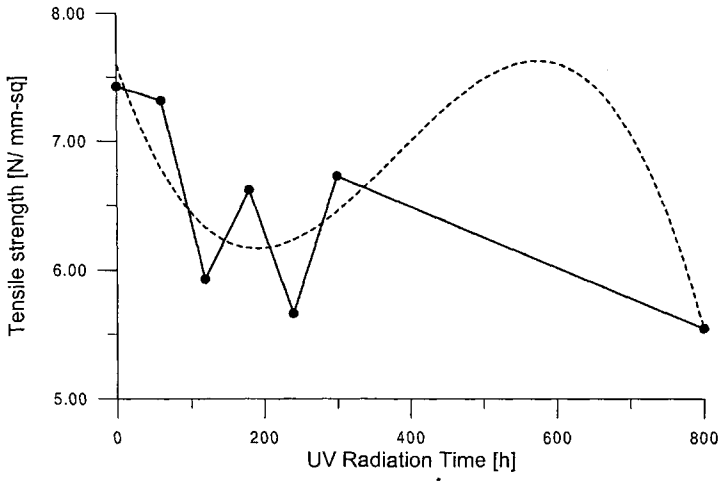

Fig. 1. Tensile strength of the polyethylene film with starch after 6 months soil burial test (empirical values and the 3rd order polynomial fit).

Conclusions

1. The soil microorganisms have statistically significant impact on the degradation of the polyethylene film with starch exposed previously to UV-radiation.
2. The polynomial of the 3-rd order is the best model of tensile strength of the polyethylene film with starch exposed to combined effect of UV-radiation and soil burial test.

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POŁĄCZONY WPŁYW PROMIENI UV I MIKROORGANIZMÓW GLEBOWYCH NA BIODEGRADACJĘ OPAKOWANIOWEJ FOLII POLIETYLENOWEJ Z DODATKIEM SKROBI

Streszczenie

Celem pracy było zbadanie w warunkach laboratoryjnych połączonego wpływu fotodegradacji i biodegradacji na właściwości mechaniczne folii opakowaniowej z polietylenu z dodatkiem 5% skrobi (MALEN E FABS 23 DO 22 produkcji Zakładów Chemicznych w Kędzierzynie Koźlu). Folię o grubości 0,04-0,1 mm naświetlano promieniami UV przez okres 60 h, 120 h, 180 h, 240 h, 300 h i 800 h przy użyciu niskoprężnych lamp rtęciowych Philips UV-A TL/05 (moc 15 W, moc UV-A 2,1 W, max. emisji 365 nm). Następnie poddano ją przez 24 tygodnie działaniu mikroorganizmów metodą testu glebowego w temp. 28–30°C i wilgotności względnej 20–30%. Stopień degradacji polietylenu oceniano na podstawie zmian naprężenia maksymalnego. Otrzymane wyniki poddano analizie wariancji. Z przeprowadzonych badań wynika, że: 1) mikroflora gleby wpływa w sposób statystycznie istotny na degradację folii polietylenowej z 5% dodatkiem skrobi, 2) właściwości mechaniczne badanej folii polietylenowej, poddanej działaniu promieni UV, ulegają trójfazowym zmianom, najlepiej opisanym przez model, w którym czas naświetlania występuje w postaci wielomianu stopnia trzeciego.