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The Synergistic Effect of Chlorinated Rubber and Other Flame Retardants Additives for Low Density Polyethylene Resin

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Abstract: ***In this work, aluminum trihydroxide Al(OH) $_3$ (additive I), Chlorinated rubber CR (additive II), Aluminum trihydroxide Al(OH) $_3$ with Chlorinated rubber (1:1) (additive III) were used as flame retardants for low-density polyethylene (LDPE) in the weight ratios of (0,3,5,7,10 and 12) %, by preparing films of (130*130*3) mm in dimensions. Three standard test methods were used to measure the flame retardation which are : ASTM :D-2863 to measure the limiting oxygen index (LOI),ASTM: D-635 to measure the rate of burning (R.B) & ASTM :D-3014 to measure the maximum height of flame (H). Results obtained from these tests indicated that,all the additives have a good effect as flame retardants for low-density polyethylene (LDPE). Additive III was the best,due to the synergistic effect.***

Keywords: low-density polyethylene (LDPE) ; flame retardant ;Combustion retardation

1. Introduction

Polymers are chemical compounds or mixtures of compounds consisting of a relatively large number of repeating structural units[1].The last few decades have seen a tremendous increase in the use of polyethylene[2],polyethylene is one of the most important polyolefins [3].

Polyethylene or polythene (IUPAC name polyethene or poly (ethylene)) is a thermoplastic commodity heavily used in packaging and having the repeating mer molecule structural unit of (C_2H_4) [4,5]. The polymer is easily flammable and so flame retardancy becomes an important requirement [6], and has became a basic and important requirement [7].

The composite polymeric materials are used in a large variety of applications because they often possess mechanical properties[8].Composite materials are those formed by the combination of two or more materials to achieve properties that are superior to those of its constituents[9].

The design goal of a composite is to achieve a combination of properties that is not displayed by any single material, and also to incorporate the best characteristics of each of the component materials [9]. The flame-retardant chemical compounds that modulate the pyrolysis reactions of polymers or oxidation reactions implied in the combustion by slowing them or by inhibiting them[10], and can be combined successfully extinguish the fire, both in the gas phase or solid, because the flammability is a function of both solid phase chemistry and gas[11].

Flame retardants are substances used in plastics, textiles and other materials to prevent fires[12], some of them cause the treated material to the character thus inhibiting the process of pyrolysis. Others remove flammable gases by reaction with hydrogen and hydroxide radicals [13]. On the surface of the burning polymers stopping the combustion.

2. Material and Methods

1- Materials

- Low density polyethylene (LDPE) was supplied from USI Corporation-*Taiwan*.
- Flame-retardants;Aluminum trihydroxide Al(OH)3 supplied from Merck,Darmstadt with purity 99.5%; Chlorinated rubber supplied from Industries Modern Painting Company - Iraq.

2-Tests

- Limiting Oxygen Index (LOI) measurement,is widely used for measuring the flammability of polymers according to ASTM: D-2863[14].
- Measurement of rate of burning (R.B), average extent of burning (A.E.B) and average time of burning (A.T.B) according to ASTM: D-635[15].
- Measurement of maximum height of flame (H) of the burning polymer and the amount of loss in weight of polymer as a result of combustion were done according to ASTM: D- 3014 [16].

3- Preparation of samples

The samples were prepared in the dimensions of (100×100×3) mm, three sheets of Low Density Polyethylene (LDPE) prepared for each percentage weight (3, 5, 8, 10 & 12%) with the additives I, II, and III.These samples were laboratory prepared according to reported method.[17]

3. Results and Discussions

1-Measurement of LOI using ASTM: D-2863

Limiting oxygen index (LOI) is defined as the minimum percentage of O_2 in a mixture of (oxygen + nitrogen) that will just support flaming combustion, which is necessary for the continuation flammable of specimen for more than three minutes at least. The efficiency of the additives I, II and III was in the following order: III > II > I

The results are displayed in Table (1) represented by Fig. (1).

Table 1: Results of LOI According to ASTM: D-2863 for the LDPE with different percentages of the additives

Additives%	LOI					
	Non	3%	5%	8%	10%	12%
I	18.8	19.83	20.23	21.10	21.56	22.02
II	18.8	20.63	21.41	22.17	22.77	23.56
III	18.8	21.38	22.25	23.07	23.73	24.88

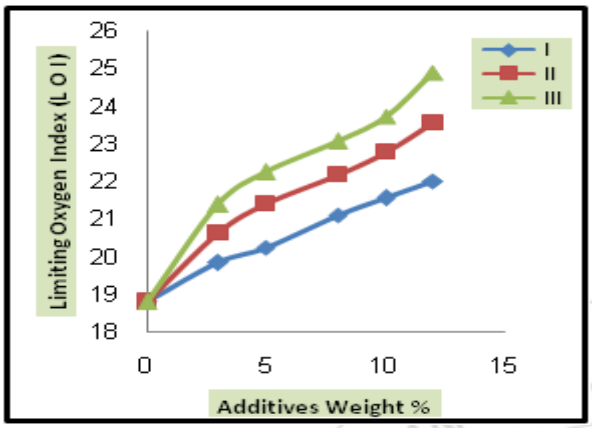

Figure 1: Relationship between Limiting Oxygen Index (LOI) and the Percentages of Additive for LDPE

2-Measurement of rate of burning (R.B), according to ASTM: D-635:

The results obtained from these tests showed that the rate of burning (R.B) of low density polyethylene (LDPE) resin with the additives has a continuous reduction with increasing the percentage weight of additives, as in Tables (2,3and 4), Fig. (2). These results indicated that, the efficiency of the additives is also following the order :
III> II>I as in the test of LOI.

Table 2: Rate of burning (R.B) of low density polyethylene (LDPE) resin with additives (I)

% / Test	Non	3	5	8	10	12
R.B(cm/min)	**3.01**	**2.31**	**2.04**	**1.86**	**1.76**	**1.57**
AEB(cm)	**10**	**10**	**10**	**10**	**10**	**10**
ATB(min)	**3.32**	**4.32**	**4.89**	**5.35**	**5.68**	**6.35**
S.E	-	-	-	-	-	-
N.B	-	-	-	-	-	-

Table 3: Rate of burning (R.B) of low density polyethylene (LDPE) resin with additives (II)

% / Test	Non	3	5	8	10	12
R.B(cm/min)	**3.01**	**1.99**	**1.82**	**1.60**	**1.45**	-
AEB(cm)	**10**	**10**	**10**	**10**	**10**	-
ATB(min)	**3.32**	**5.02**	**5.48**	**6.25**	**6.89**	-
S.E	-	-	-	-	-	**yes**
N.B	-	-	-	-	-	**yes**

Table 4: Rate of burning (R.B) of low density polyethylene (LDPE) resin with additives (III)

% / Test	Non	3	5	8	10	12
R.B(cm/min)	**3.01**	**1.89**	**1.63**	**1.44**	**1.36**	-
AEB(cm)	**10**	**10**	**10**	**10**	**10**	-
ATB(min)	**3.32**	**5.29**	**6.15**	**6.94**	**7.33**	-
S.E	-	-	-	-	-	**yes**
N.B	-	-	-	-	-	**yes**

Note:
A.E.B: Average Extent of burning.
A.T.B: Average Time of Burning.
S.E: Self-Extinguishing.
N.B: Not-Burning.

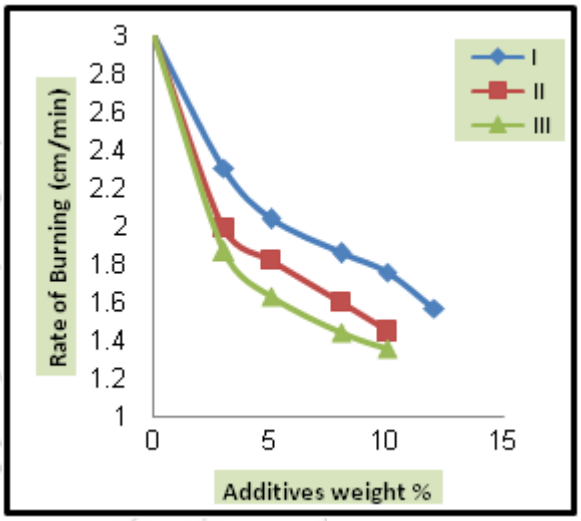

Figure 2: Relationship between Rate of Burning (R.B) and the Percentage of the Additives with LDPE

3-Measurement of maximum flame height (H) according to ASTM: D-3014:

The maximum flame height (H) decreased with increasing the percentage of additives(inversely proportional), as shown in Table(5, 6 and 7).Figure (3) shows that, e.g;Additive III caused the flame height,table (7) to be reduced from 13 without additive to 6 with 10% additive. The best efficiency of additive (III) in the three test methods is due to the composition of the chlorinated rubber which consists of about 70% chlorine that increases the efficiency. The mechanism of halogen-containing flame retardants was because of releasing halogen radicals that react with high energy H^0 and OH^0 which are responsible of combustion continuation of the polymeric materials [18]. In addition, the total liberation of the gases that help to reduce the height of the flames, such as H_2O,CO and CO_2 create an atmosphere to spread the heat insulator and non-combustible works.

Table 5: Maximum flame height (H) of low density polyethylene (LDPE) resin with additive (I)

% / Test	Non	3	5	8	10	12
W_1	3.28	3.21	3.29	3.38	3.44	3.51
W_2	1.23	1.28	1.32	1.39	1.44	1.53
PWR%	63.41	60.12	59.87	58.87	58.13	56.41
H	13	11.7	10.5	9.5	8.5	7

Table 6: Maximum flame height (H) of low density polyethylene (LDPE) resin with additive (II)

% / Test	Non	3	5	8	10	12
W_1	3.28	3.26	3.32	3.40	3.45	3.53
W_2	1.23	1.30	1.39	1.44	1.50	-
PWR%	63.41	60.12	58.13	57.64	56.52	-
H	13	10.5	9.5	8	7	-

Table 7: Maximum flame height (H) of low density polyethylene (LDPE) resin with additive (III)

% / Test	Non	3	5	8	10	12
W_1	3.28	3.32	3.37	3.41	3.46	3.50
W_2	1.23	1.32	1.39	1.45	1.49	-
PWR%	63.41	60.24	58.75	57.47	56.93	-
H	13	9.5	8	7	6	-

Note:
W_1: Weight of sample before burning (gm).
W_2: Weight of the loss from sample after burning (gm).
H: Maximum Flame Height (cm).
PWR: The Percentage of Weight (%).

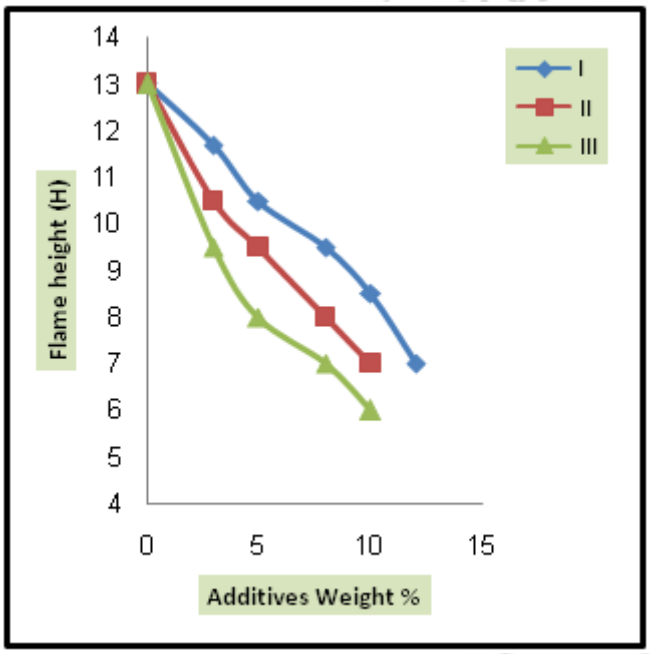

Figure (3-3): The Relationship between Flame Height (H) and the Percentage of the Additives with LDPE

4. Conclusions

The flame-retardancy efficiency of the additives I, II and III appeared to follow the order: III > II > I. The additive (III) gave the best results in blocking the flammability of LDPE comparing with other additives due to its composition. The (LOI) increased with increasing the weight percentages of the additives The rate of burning (R,B) and the flame height (H), decreased with increasing the weight percentages of the additives.

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