CHAPTER 4

RESULTS

The progress of photodegradation of blow moulding poly(vinyl chloride) with and without photosensitizer, benzophenone or anthraquinone , were observed both by natural weathering and accelerated irradiation test. Blow moulding poly(vinyl chloride) sheets contain the photosensitizer at concentrations of 0 % , 0.1 % , 0.5 % and 1.0 % by weight for natural exposure and 0 % , 0.05 % , 0.1 % and 0.5 % by weight for accelerated irradiation. Unsensitized and sensitized blow moulding poly(vinyl chloride) sheets were exposed under natural weathering condition for 9 months. For the accelerating tests, the sheet samples were irradiated with a medium pressure mercury lamp for 240 hours. The mechanical properties (tensile strength, elongation at rupture) and physical properties (molecular weight, optical absorption , visual inspection) of all samples before and after irradiation were used for investigating the photodegradation processes.

4.1 Natural Weathering test

4.1.1 Result of tensile properties

The example of load-elongation (stress-strain) traces of both irradiated unsensitized and sensitisized samples is shown in Fig. 4.1a - 4.1b. The decreasing of elongation at rupture of the irradiated polymer can be seen in Fig. 4.3a and b while the load of every sample is slightly changed with irradiation time as in Fig. 4.2a and b. Thus, for this work , the elongation at rupture will be used for showing the degradation tendency of the investigation of the photodegradation process.

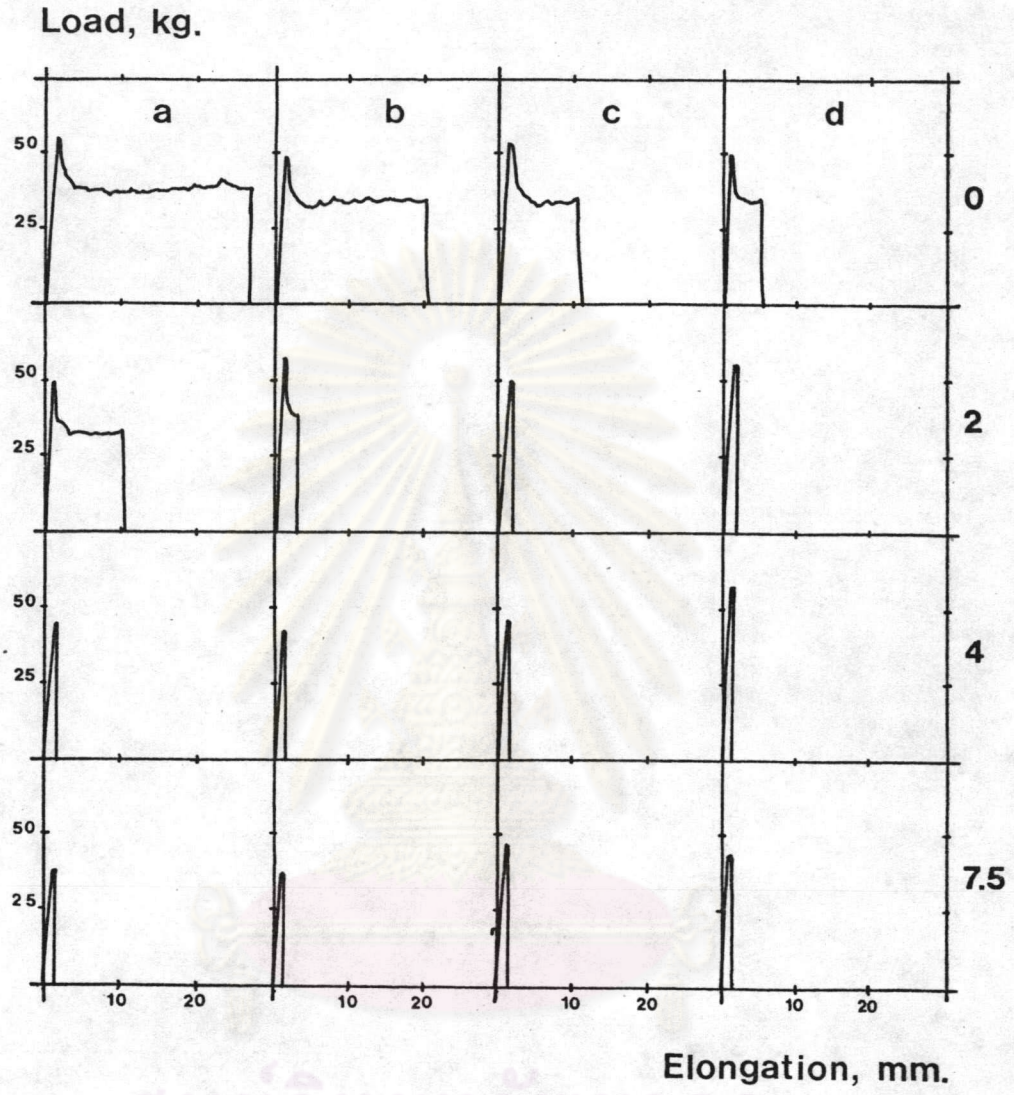


Fig. 4.1a Load-Elongation of outdoor exposure samples at various exposure time (indicated on curve in months) :
a) 0 % photosensitizer, b) 0.1 % anthraquinone, c) 0.5 % anthraquinone and d) 1.0 % anthraquinone

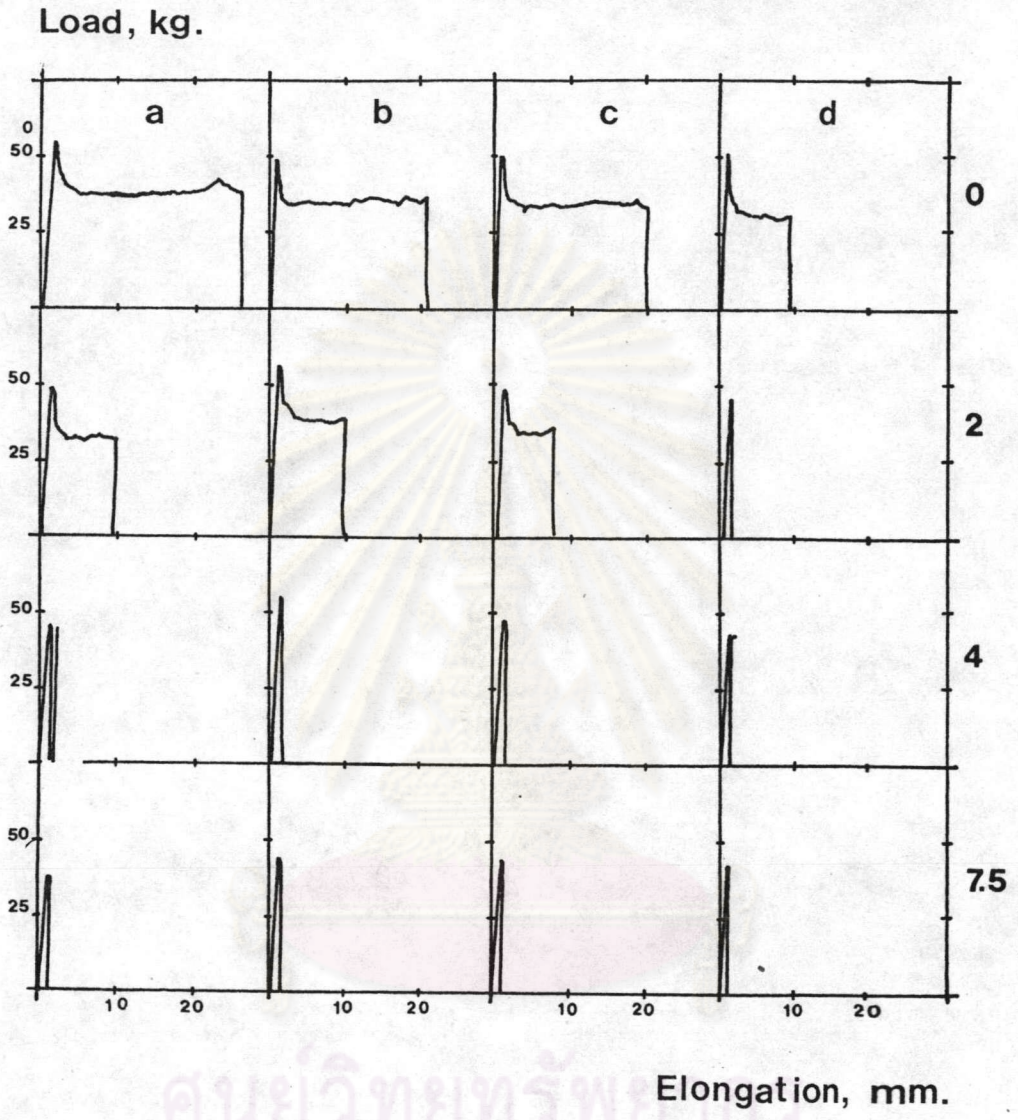


Fig. 4.1b Load-Elongation of outdoor exposure samples at various exposure time (indicated on curve in months) :
a) 0 % photosensitizer, b) 0.1 % benzophenone, c) 0.5 % benzophenone and d) 1.0 % benzophenone

TABLE 4-1a The relationship of tensile strength and the exposure time for PVC outdoor exposure samples (photosensitizer : anthraquinone)

Exposure time (months)	Tensile strength (kg/mm^2)			
	0% ANT	0.1% ANT	0.5% ANT	1.0% ANT
original	5.55	5.90	5.85	6.10
1.0	5.85	6.20	5.85	5.90
2.0	5.90	5.85	5.85	6.20
3.0	6.30	5.95	4.90	5.95
4.0	6.00	5.20	5.40	5.95
5.0	6.00	5.20	5.35	6.00
6.0	5.65	5.15	5.00	5.35
7.5	4.90	4.25	4.20	4.55
9.0	3.95	3.80	3.80	3.55

TABLE 4-1b The relationship of tensile strength and the exposure time for PVC outdoor exposure samples (photosensitizer : benzopheonone)

Exposure time (months)	Tensile strength (kg/mm^2)			
	0% BEN	0.1% BEN	0.5% BEN	1.0% BEN
original	5.55	5.85	5.90	6.15
1.0	5.85	5.50	5.95	6.20
2.0	5.90	6.25	6.05	5.35
3.0	6.30	6.55	6.20	5.60
4.0	6.00	5.95	5.90	5.65
5.0	6.00	5.30	5.40	5.70
6.0	4.95	4.60	4.60	4.45
7.5	4.10	4.25	4.78	4.90
9.0	3.75	3.90	3.85	3.30

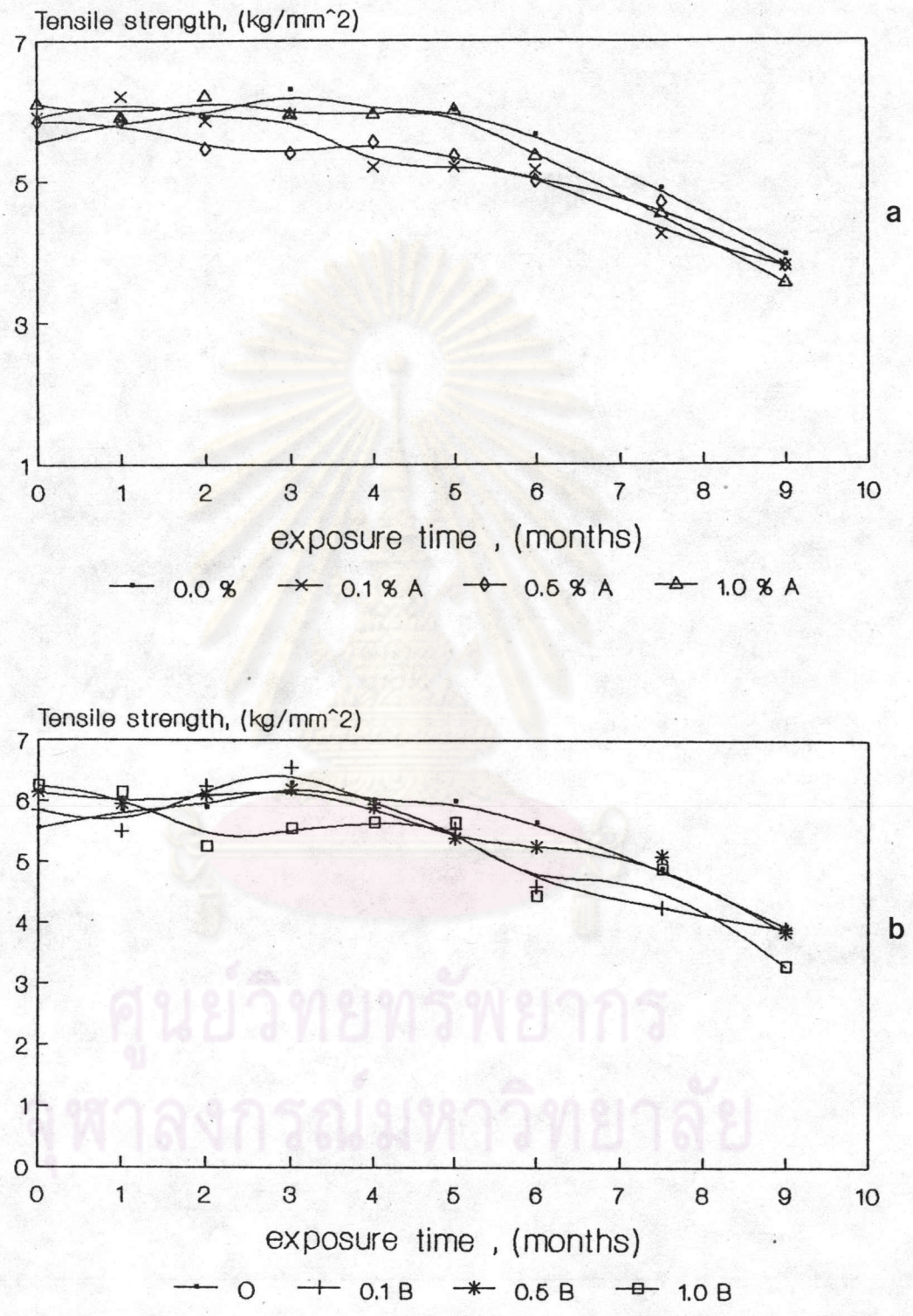


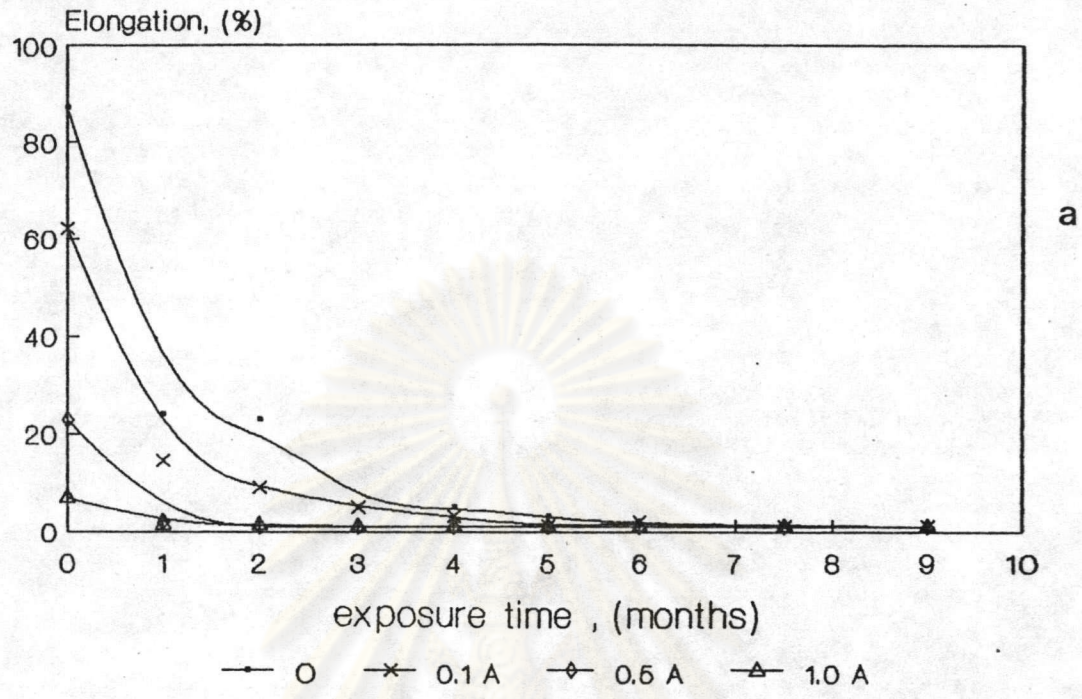
Fig. 4.2 Tensile strength of PVC samples at various concentrations of photosensitizer as a function of outdoor exposure time. : a) anthraquinone, b) benzophenone

TABLE 4-2a The relationship of % elongation and the exposure time for PVC outdoor exposure samples (photosensitizer : anthraquinone)

Exposure time (months)	Elongation at rupture (%)			
	0% ANT	0.1% ANT	0.5% ANT	1.0% ANT
original	87.00	62.00	23.00	7.00
1.0	28.00	14.50	2.00	1.50
2.0	23.30	9.00	1.00	1.50
3.0	11.00	5.00	1.00	1.00
4.0	5.00	3.00	1.00	1.00
5.0	3.00	1.00	1.00	1.00
6.0	1.50	2.00	1.00	1.00
7.5	1.50	1.50	1.00	1.00
9.0	1.00	1.00	1.00	1.00

TABLE 4-2b The relationship of % elongation and the exposure time for PVC outdoor exposure samples (photosensitizer : benzopheonone)

Exposure time (months)	Elongation at rupture (%)			
	0% BEN	0.1% BEN	0.5% BEN	1.0% BEN
original	87.00	71.00	65.00	22.00
1.0	28.00	28.63	13.00	5.00
2.0	23.30	18.50	13.50	1.50
3.0	11.00	9.00	2.00	2.00
4.0	5.00	4.00	1.50	1.80
5.0	3.00	3.50	1.00	1.00
6.0	1.50	1.50	1.00	1.00
7.5	1.50	1.00	1.00	1.00
9.0	1.00	1.00	1.00	1.00



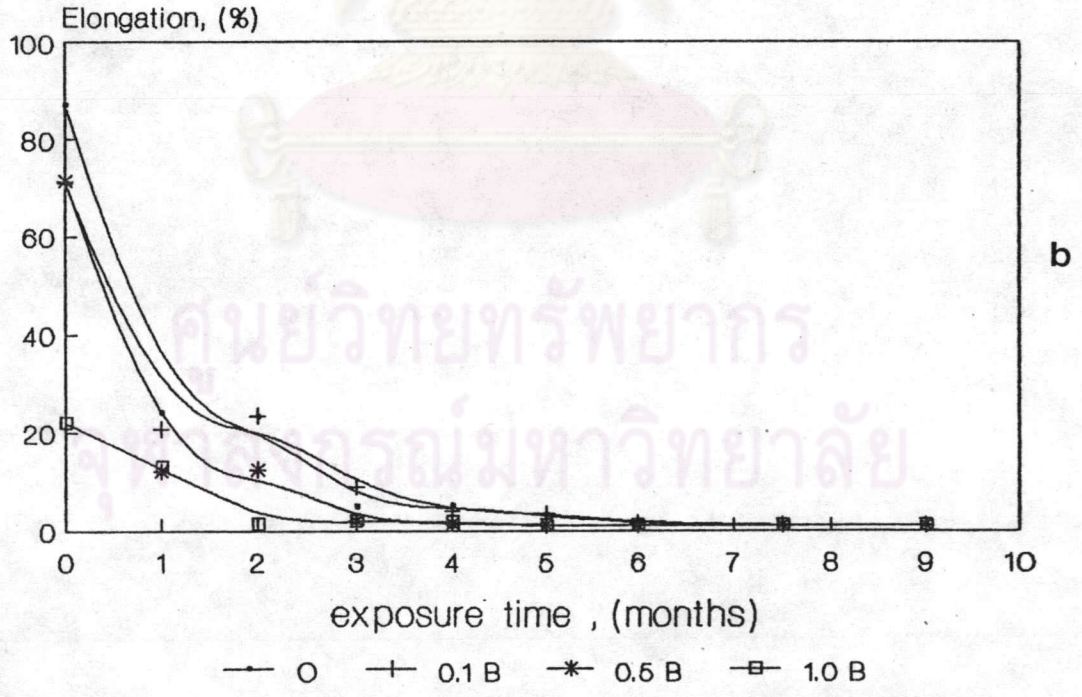


Fig. 4.3 Elongation at break of PVC samples at various concentrations of photosensitizer as a function of outdoor exposure time. : a) anthraquinone, b) benzophenone

4.1.2 Result of molecular weight

(a) Unsensitized PVC samples

The molecular weight of unsensitized PVC samples decrease very slightly within the first four months of the exposure periods. After then, the molecular weight decreases gradually with exposure time.

(b) Sensitized PVC samples

- Anthraquinone sensitized PVC

The molecular weight of the PVC contained 0.1 % anthraquinone decreases slightly at the early months of exposure. While the molecular weight of PVC contained 0.5 % anthraquinone increases from the original value of the unirradiated at the first month and then decrease at the second month as well as the occurance of the insoluble gel residues. The molecular weight of PVC contained 1.0 % anthraquinone decreased gradually since the beginning of the exposure and insoluble gel residues were observed since the first months of the exposure. The soluble fraction was separated from the insoluble part by filtration and then taken for further measurement of the molecular weight.

- Benzophenone sensitized PVC

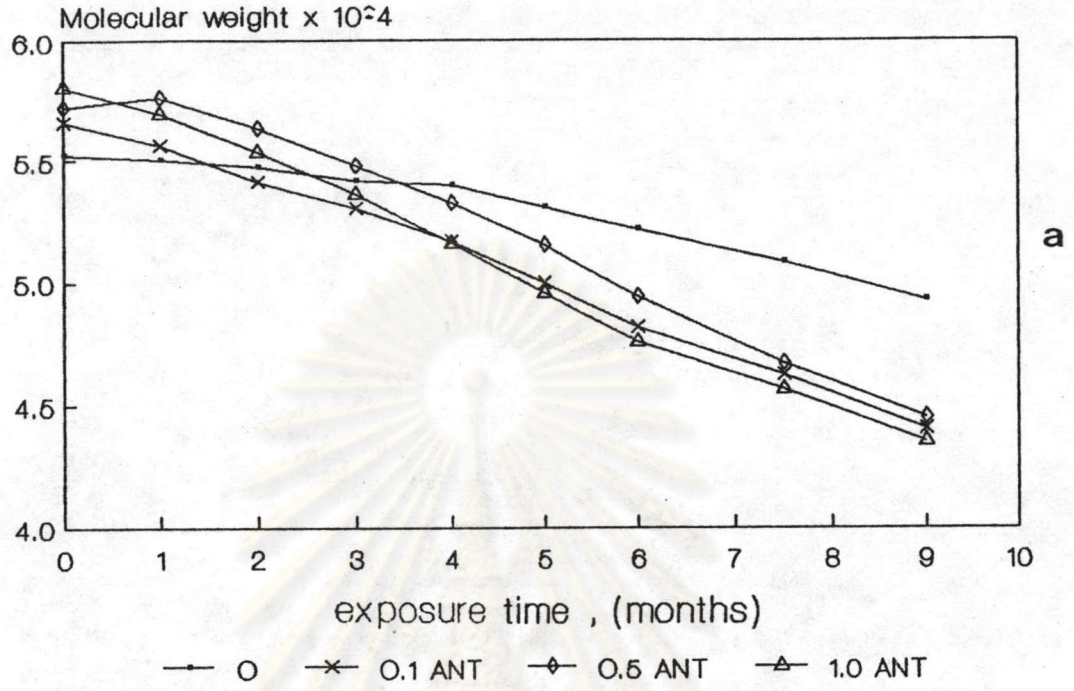
The molecular weight of sensitized PVC samples decrease slightly during the early months of irradiation. The trend of decreasing in molecular weight is the same as anthraquinone sensitizer. As the polymer contains more photosensitizer, the lower molecular weight receives. The gel particles for every concentration is not noticeable except at the concentration of 1.0 % by weight after 7.5 months of exposure periods.

Table 4-3a Relation between intrinsic viscosity [η] and average molecular weight (MW) for PVC outdoor exposure samples
(photosensitizer : anthraquinone)

Exposure time (months)	Intrinsic viscosity [η]	molecular weight x 10^-4
PVC-0% ANT		
original	0.7305	5.5220
1	0.7290	5.5070
2	0.7258	5.4760
3	0.7200	5.4190
4	0.7178	5.3980
5	0.7086	5.3080
6	0.6992	5.2170
7.5	0.6854	5.0840
9	0.6692	4.9280
PVC-0.1% ANT		
original	0.7445	5.6600
1	0.7349	5.5660
2	0.7194	5.4130
3	0.7081	5.3030
4	0.6940	5.1670
5	0.6765	4.9980
6	0.6578	4.8190
7.5	0.6372	4.6240
9	0.6138	4.4050
PVC-0.5% ANT		
original	0.7509	5.7230
1	0.7549	5.7630
2	0.7420	5.6360
3	0.7261	5.4790
4	0.7102	5.3240
5	0.6924	5.1510
6	0.6708	4.9440
7.5	0.6424	4.6730
9	0.6145	4.4110
PVC-1.0% ANT		
original	0.7593	5.8070
1	0.7482	5.6970
2	0.7323	5.5400
3	0.7141	5.3620
4	0.6934	5.1610
5	0.6722	4.9570
6	0.6513	4.7580
7.5	0.6309	4.5650
9	0.6011	4.2870

Table 4-3b Relation between intrinsic viscosity [η] and average molecular weight (MW) for PVC outdoor exposure samples
(photosensitizer : benzophenone)

Exposure time (months)	Intrinsic viscosity [η]	molecular weight x 10^-4
PVC-0% ANT		
original	0.7305	5.5220
1	0.7290	5.5076
2	0.7258	5.4760
3	0.7200	5.4590
4	0.7178	5.3980
5	0.7086	5.3080
6	0.6992	5.2170
7.5	0.6854	5.0840
9	0.6692	4.9280
PVC-0.1% BEN		
original	0.7412	5.6280
1	0.7365	5.5810
2	0.7266	5.4840
3	0.7161	5.3810
4	0.7018	5.2420
5	0.6851	5.0810
6	0.6698	4.9340
7.5	0.6490	4.7360
9	0.6239	4.4990
PVC-0.5% BEN		
original	0.7480	5.6960
1	0.7445	5.6600
2	0.7367	5.5830
3	0.7194	5.4140
4	0.7031	5.2550
5	0.6840	5.0700
6	0.6654	4.8920
7.5	0.6411	4.6610
9	0.6163	4.4280
PVC-1.0% BEN		
original	0.7555	5.7690
1	0.7450	5.6650
2	0.7319	5.5360
3	0.7175	5.3950
4	0.7017	5.2410
5	0.6843	5.0730
6	0.6665	4.9020
7.5	0.6435	4.6840
9	0.6157	4.4230



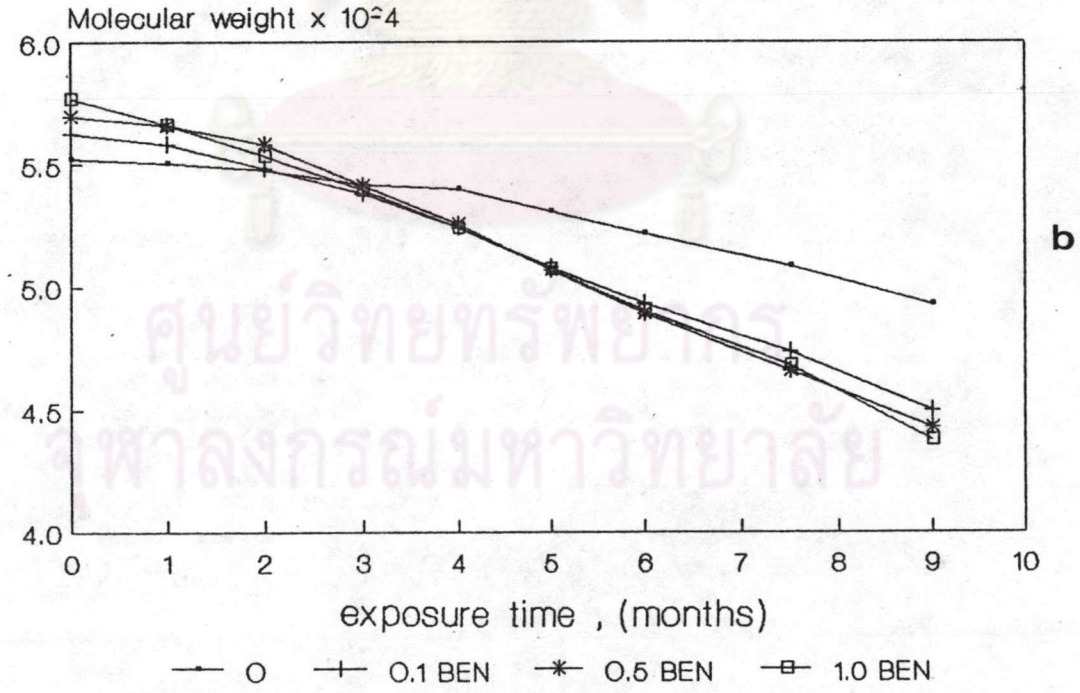


Fig. 4.4 Molecular weight traces of PVC samples at various concentrations of photosensitizer as a function of outdoor exposure time. : a) anthraquinone, b) benzophenone

4.1.3 Result of Fourier Transform infrared absorption

The Fourier transform infrared absorption spectra of the exposed samples are obtained and the typical spectra are shown in Fig. 4.5. Absorption peak are observed in

(a) the 1735 cm^{-1} band corresponds to the presence of the carbonyl group in the PVC chain.

(b) the intensity of the maximum of a broad band at 3460 cm^{-1}, reflects the concentration of hydroxyl group in PVC sheets.

(c) The poly(vinyl chloride) band at 638 cm^{-1} serves as internal standard to which the absorbances of the other bands that related.

The relative absorbance of PVC carbonyl groups (A_{1735}) is plotted in Fig. 4.6 a and b as a function of exposure time. The rate of formation of carbonyl group for the sensitized samples increase remarkable at the begining and subsequently slow down. While the carbonyl formation of the unsentisized samples increase slowly at the begining. The formation of carbonyl group in the anthraquinone system is higher than the benzophenone one.

Fig. 4.7 a and b shown the changing intensity of the hydroxyl absorption band (A_{3460}) with exposure time . The absorption of hydroxyl bands increase slowly at the early stage of the exposure and then increase rapidly at the exposure time that correspond to the greatest changing in the tensile properties.

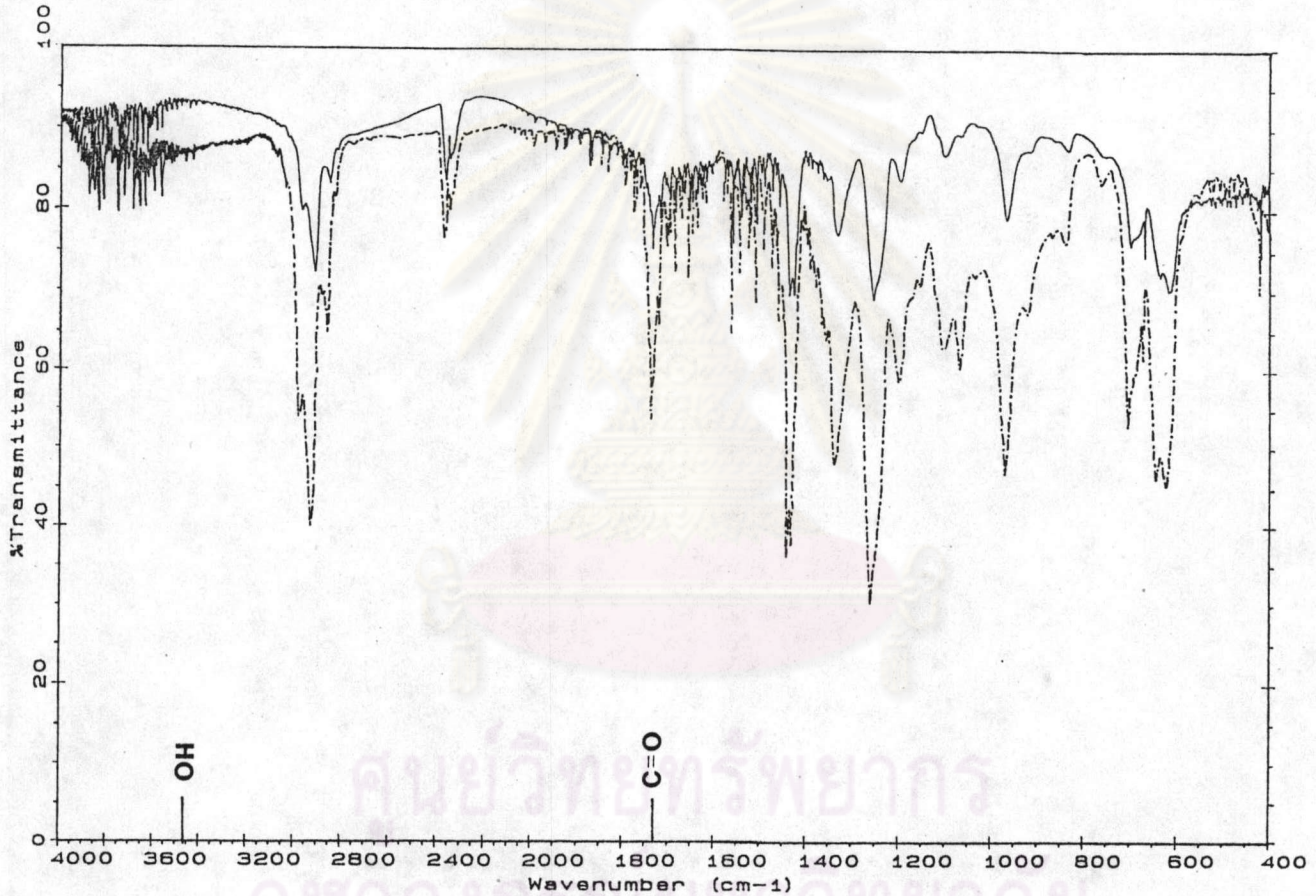


Fig. 4.5.1 FT-IR spectra of PVC outdoor exposure samples at 0 % photosensitizer

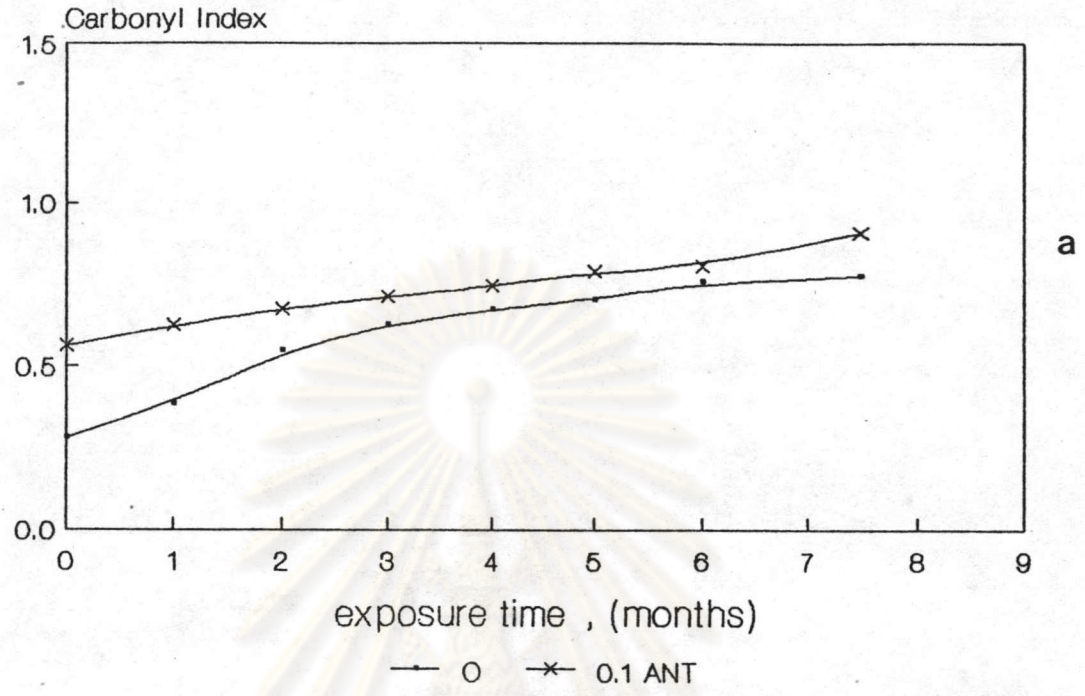
--------- unirradiated , -·-·-·-·- irradiated for 6 months

Table 4.4a Carbonyl Index in PVC chain of outdoor exposure samples (sensitizer : anthraquinone)

Exposure Time	Carbonyl Index (1735 cm^-1)	
	0 %	0.1% A
original	0.280	0.561
1 month	0.383	0.624
2 months	0.548	0.674
3 months	0.627	0.713
4 months	0.675	0.745
5 months	0.705	0.790
6 months	0.761	0.807
7.5 months	0.775	0.918

Table 4.4b Carbonyl Index in PVC chain of outdoor exposure samples (sensitizer : benzophenone)

Exposure Time	Carbonyl Index (1735 cm^-1)			
	0 %	0.1% B	0.5% B	1.0% B
original	0.280	0.410	0.610	0.659
1 month	0.383	0.519	0.670	0.680
2 months	0.548	0.542	0.672	0.705
3 months	0.627	0.638	0.734	0.745
4 months	0.675	0.686	0.761	0.797
5 months	0.705	0.735	0.810	0.812
6 months	0.761	0.768	0.814	0.896
7.5 months	0.775	0.867	0.887	0.965



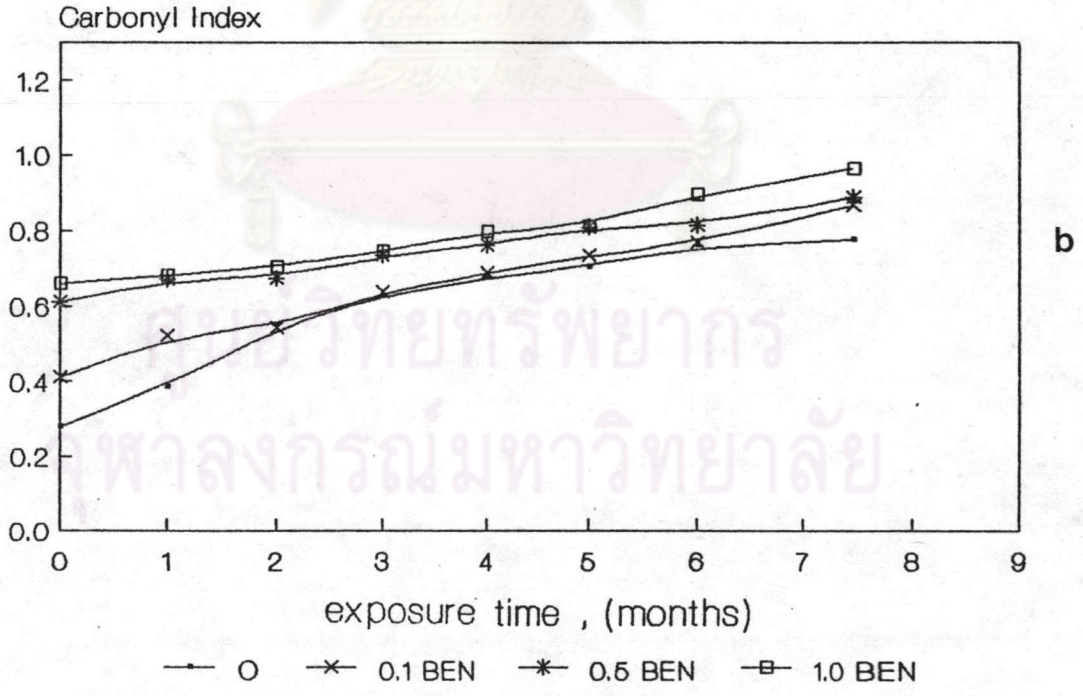


Fig. 4.6 Change of the relative FT-IR absorbance of carbonyl group in PVC chains as a function of outdoor exposure time at various concentrations of photosensitizer. :
a) anthraquinone, b) benzophenone

Table 4.5a Hydroxyl Index in PVC chain of outdoor exposure samples (sensitizer : anthraquinone)

Exposure Time	Hydroxyl Index (3460 cm^-1)	
	0 %	0.1% A
original	0.242	0.382
1 month	0.305	0.584
2 months	0.340	0.668
3 months	0.391	0.778
4 months	0.487	0.948
5 months	0.577	1.083
6 months	0.604	1.151
7.5 months	0.651	1.233

Table 4.5b Hydroxyl Index in PVC chain of outdoor exposure samples (sensitizer : benzophenone)

Exposure Time	hydroxyl Index (3460 cm^-1)			
	0 %	0.1% B	0.5% B	1.0% B
original	0.242	0.273	0.353	0.406
1 month	0.305	0.335	0.435	0.486
2 months	0.340	0.372	0.592	0.653
3 months	0.391	0.500	0.748	0.887
4 months	0.487	0.623	0.944	0.982
5 months	0.577	0.716	1.040	1.174
6 months	0.604	0.874	1.211	1.231
7.5 months	0.651	0.923	1.312	1.335

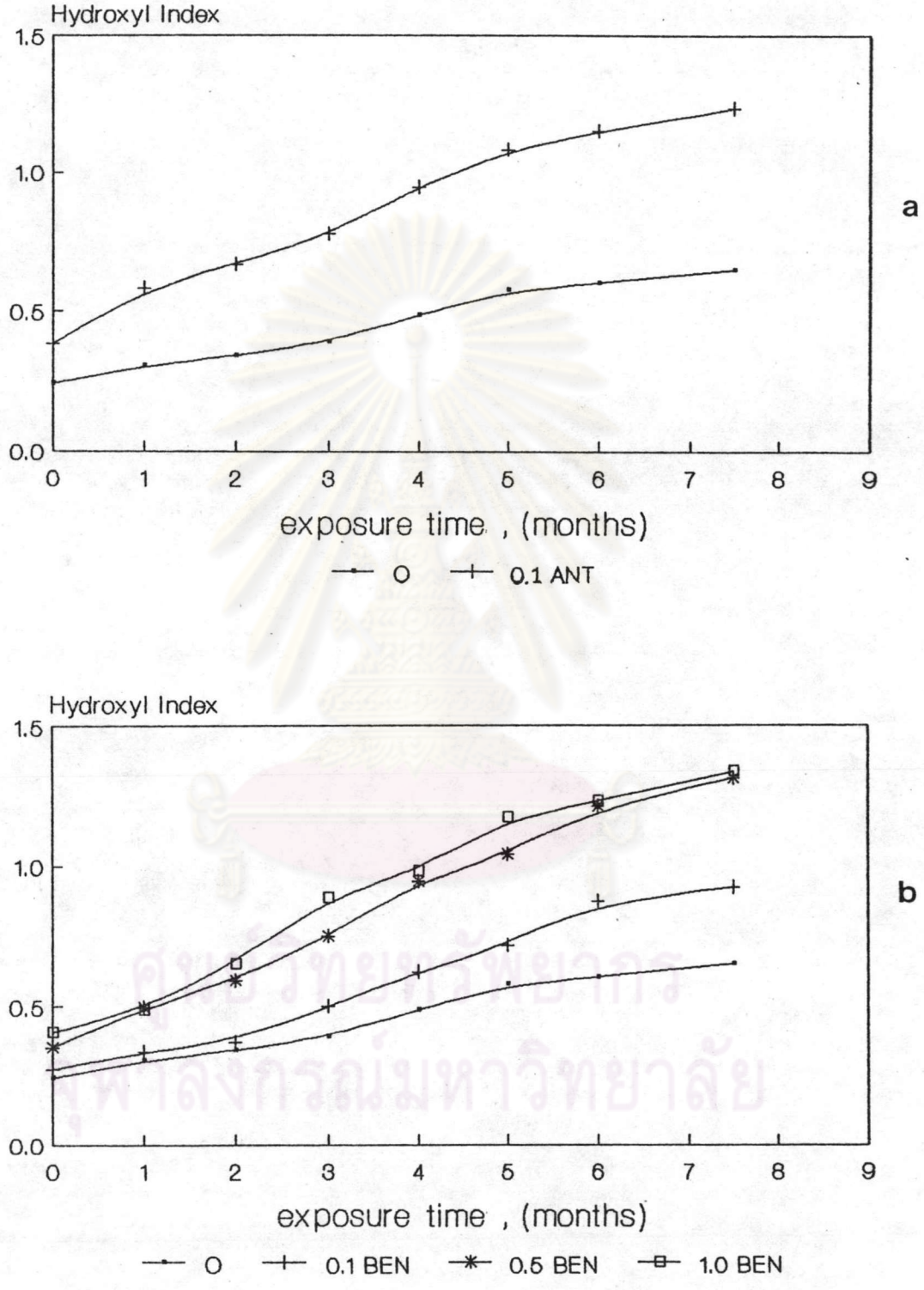


Fig. 4.7 Change of the relative FT-IR absorbance of hydroxyl group in PVC chains as a function of outdoor exposure time at various concentrations of photosensitizer. :
a) anthraquinone, b) benzophenone

4.1.4 Result of UV absorption

The UV absorption spectra is the absorption in the range between 200 - 450 nanometres. From the absorption spectra particularly for wavelength less than 350 nanometres will correspond to polyene with n = 6. For absorbance at 307 nm. the polyene of n = 4 is assigned. The absorbance at 230 and 280 nm. are due to n = 2 and 3 , respectively. The absorbance at 320 nm can be identified for the n = 5 polyene. The absorbance at 354 nm is due mainly to polyene n = 6. And absorbance at 380 and 410 nm. are due to n = 7 and 8, respectively.

a) Unsensitized PVC samples

The UV absorption spectra of the PVC samples were shown in Fig. 4.8. The absorbance of the irradiated PVC at the range 200 - 280 nm. decreased while the absorbance at the range 280 - 450 nm. increased from the original one. Thus, the polyene with n = 2 and 3 decreased whereas thepolyene with n > 4 increased with exposure time.

b) Sensitized PVC samples

The UV - visible absorption spectra of both unirradiated and irradiated PVC contained 0.1 % anthraquinone has the absorption spectra similar to the unsensitized. But the absorbance of the exposed PVC at any wavelength are higher than the other one.

The absorbance spectra of PVC contained benzophenone has the same feature as the PVC contained anthraquinone. But the absorbance of PVC containing benzophenone at any wavelength is lower than that of anthraquinone at the same concentration.

4.1.5 Result of visual inspection

The result of visual inspection are summerized in Table 4.6.

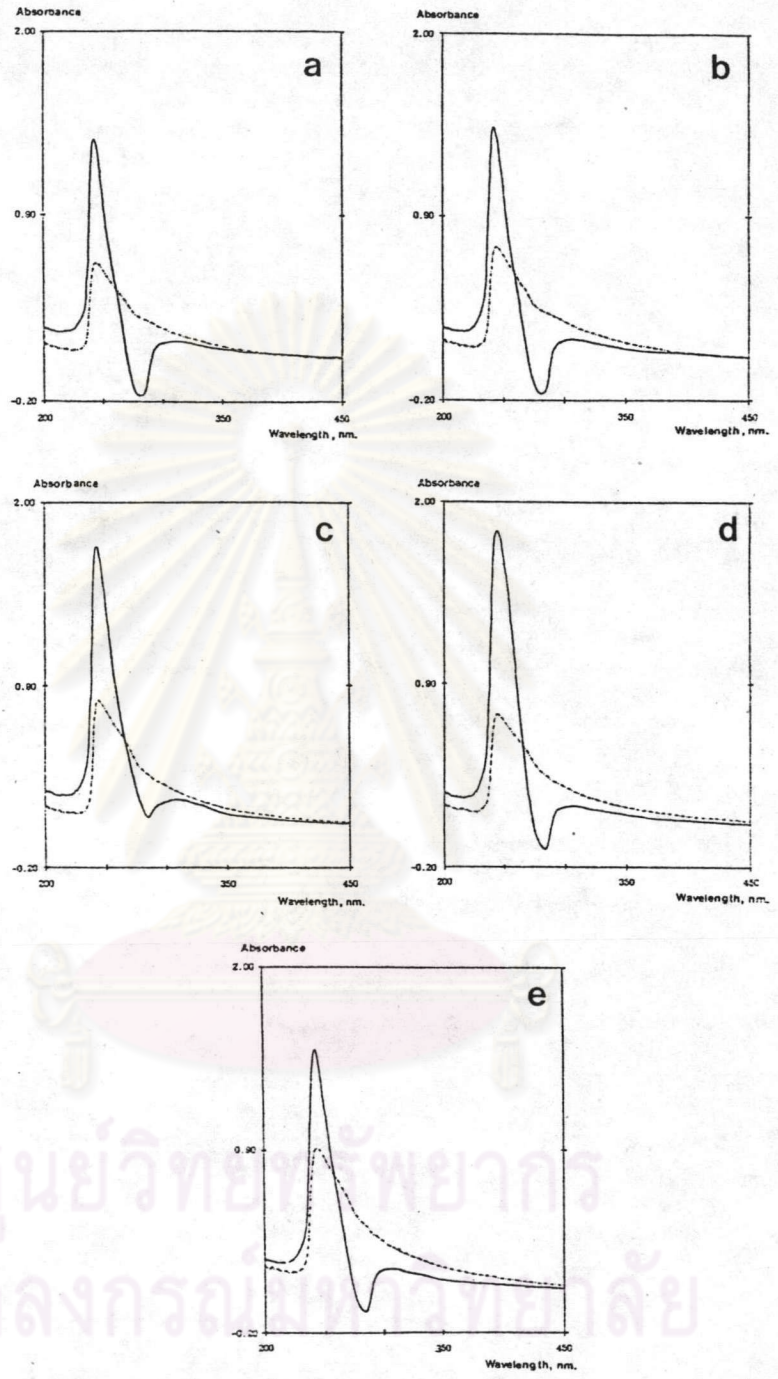


Fig. 4.8 UV spectra of PVC outdoor exposure samples at :
a) 0% photosensitizer, b) 0.1% anthraquinone, c) 0.1% benzophenone, d) 0.5% benzophenone, e) 1.0% benzophenone
-------- unirradiated, - - - - irradiated for 6 months

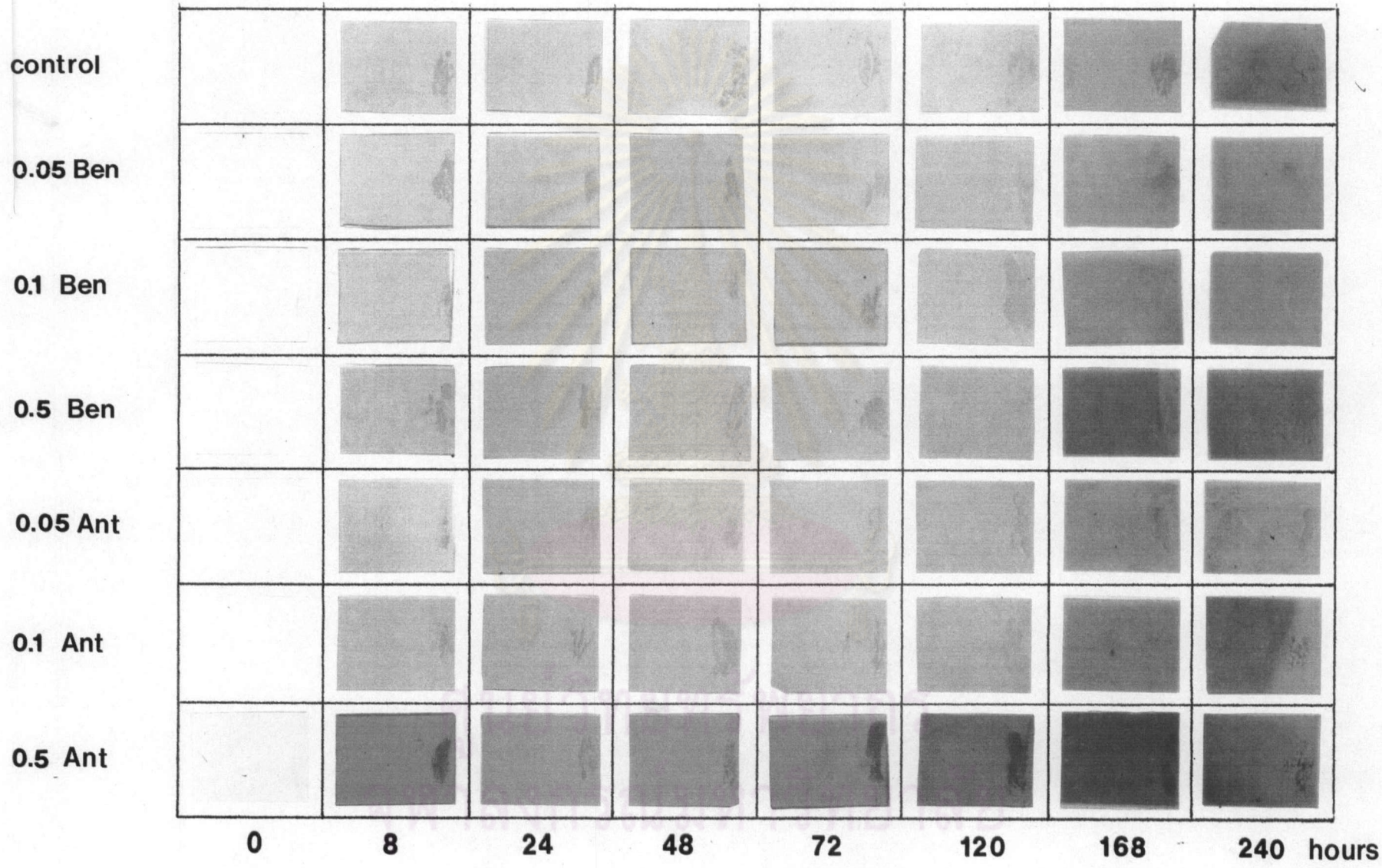


Fig. 4.9 Difference in surface changes of the accelerating exposure samples

Table 4.6 Results of visual inspection for outdoor exposure as a function of time with various concentrations of photosensitizers (anthraquinone and benzophenone)

	Results of visual inspection	Ranks of change
CONTROL colour gloss fragile	 Noticable change after 1 month exposure No change Breakable by hand after 5 months exposure	7
0.1 % BEN colour gloss fragile	 Noticable change after 1 month exposure No change Breakable by hand after 5 months exposure	6
0.5 % BEN colour gloss fragile	 Noticable yellowing after 1 month exposure No change Breakable by hand after 5 months exposure	5
1.0 % BEN colour gloss fragile	 Noticable yellowing after 1 month exposure severly change into dark brown after 7.5 months exposure No change Breakable by hand after 3 months exposure	3
0.1 % ANT colour gloss fragile	 Yellowing after 1 months and become brown after 9 months of exposure No change Breakable by hand after 3 months exposure	4
0.5 % ANT colour gloss fragile	 Browning after 1 month exposure and become black after 6 months exposure Change slightly after 5 months exposure Breakable by hand after 2 months exposure	2
1.0 % BEN colour gloss fragile	 Becoming dark brown at 1 month and severly change to black after 3 months exposure Change slightly after 3 months exposure Breakable by hand after 2 months exposure	1

4.2 Accelerating weathering test

4.2.1 Results of Tensile properties

The load-elongation (stress-strain) diagram of PVC sheet irradiated by high pressure mercury lamp 125 W. are shown in Fig. 4.10 a and b. The behavior of each samples in this diagram is the same as the samples from outdoor exposure in Fig. 4.1 a and b.

The changes in tensile strength and elongation at break with irradiation time are shown in Fig. 4.10 a and b, Fig. 4.11 a and b. The tensile strength value of both unsensitized and sensitized samples increase from its original value and then gradually decrease after 120 hours of irradiation. But the tensile strength of every irradiated samples at 240 hours is still higher than its original value , exclude for the PVC contained 0.05 % anthraquinone and 0.1 % benzophenone. The tensile strength of these samples have tendency to decrease as increasing the irradiation time.

The result of elongation at break of PVC samples containing benzophenone decrease rapidly after 8 hours of irradiation. Whereas the elongation of PVC samples containing anthraquinone increase from its original value and then decrease rapidly after 24 hours for 0.05 % A and 48 hours for 0.1 % and 0.5 % A. After 120 hours, the elongation of PVC samples containing photosensitizers show slowly decrease and have tendency to approach zero value.

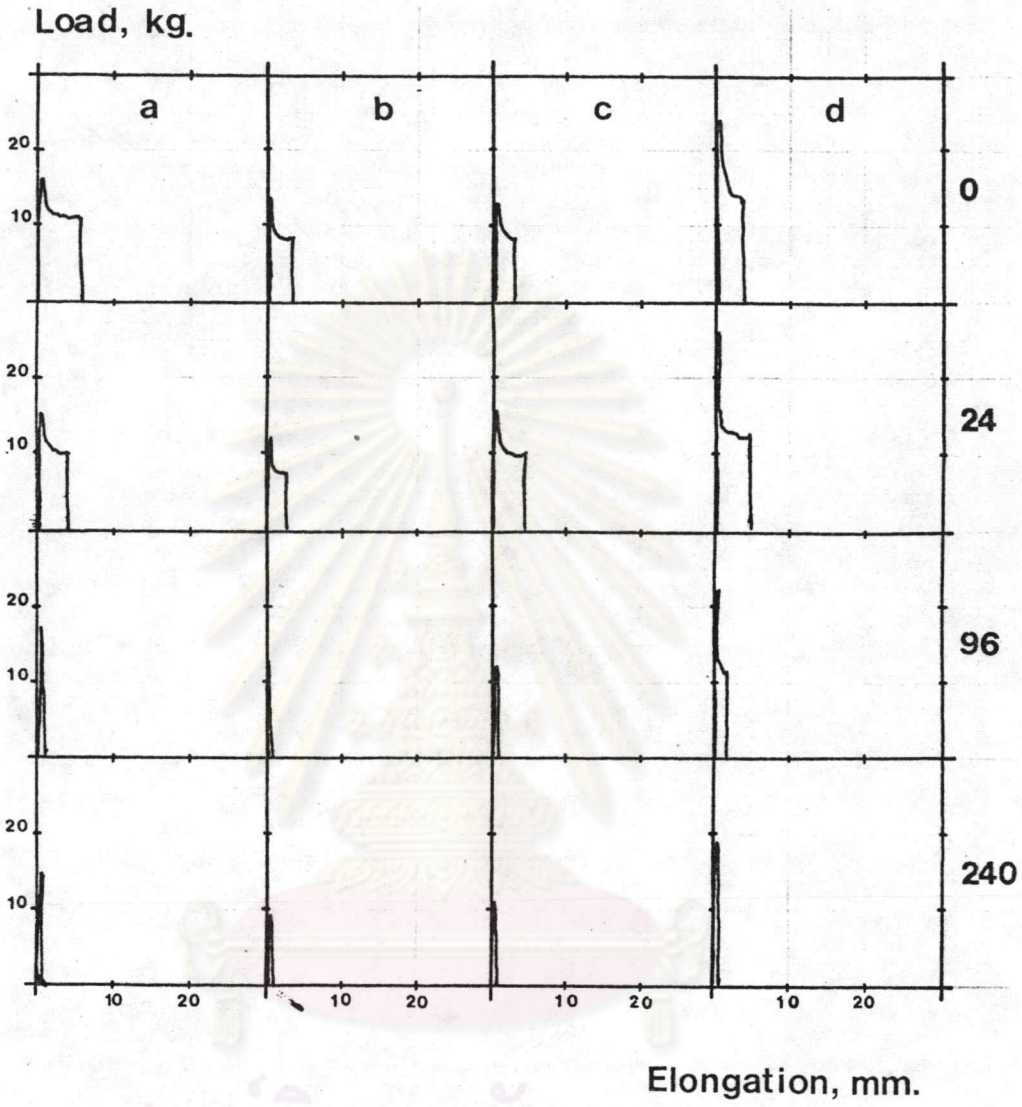


Fig. 4.10a Load-Elongation of accelerating exposure samples at various irradiation time (indicated on curve in hours) :
a) 0 % photosensitizer, b) 0.05 % anthraquinone,
c) 0.1 % anthraquinone and d) 0.5 % anthraquinone

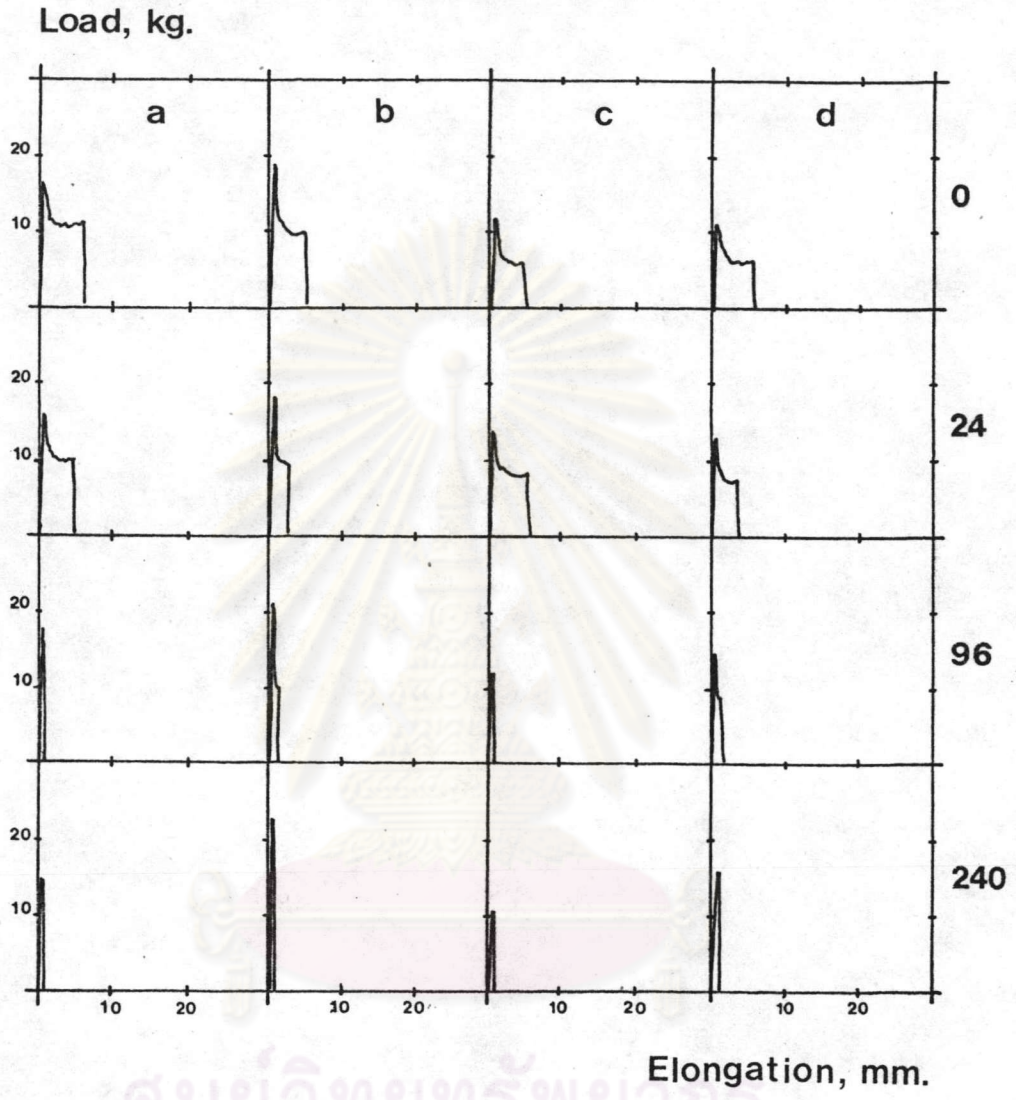


Fig. 4.10b Load-Elongation of accelerating exposure samples at various irradiation time (indicated on curve in hours) :
a) 0 % photosensitizer, b) 0.05 % benzophenone,
c) 0.1 % benzophenone and d) 0.5 % benzophenone

TABLE 4-7a The relationship of tensile strength and the irradiation time for PVC accelerating irradiated samples (photosensitizer : anthraquinone)

Irradiation time (hours)	Tensile strength (kg/mm^2)			
	0% ANT	0.05% ANT	0.1% ANT	0.5% ANT
original	6.14	6.40	6.13	6.39
8	6.25	6.52	6.46	6.41
24	6.63	6.50	6.56	6.69
48	6.71	6.41	6.66	6.61
72	6.73	6.20	7.42	6.04
120	6.88	4.67	6.76	6.51
168	6.52	4.58	6.64	6.40
240	6.33	4.43	6.42	6.37

TABLE 4-7b The relationship of tensile strength and the irradiation time for PVC accelerating irradiated samples (photosensitizer : benzopheonone)

Irradiation time (hours)	Tensile strength (kg/mm^2)			
	0% BEN	0.05% BEN	0.1% BEN	0.5% BEN
original	6.14	5.85	5.69	6.30
8	6.25	5.61	6.36	6.49
24	6.63	5.61	6.24	6.24
48	6.71	6.55	6.32	6.32
72	6.73	6.37	6.59	6.59
120	6.88	3.36	6.71	6.71
168	6.52	6.20	6.41	6.47
240	6.33	6.14	6.32	6.03

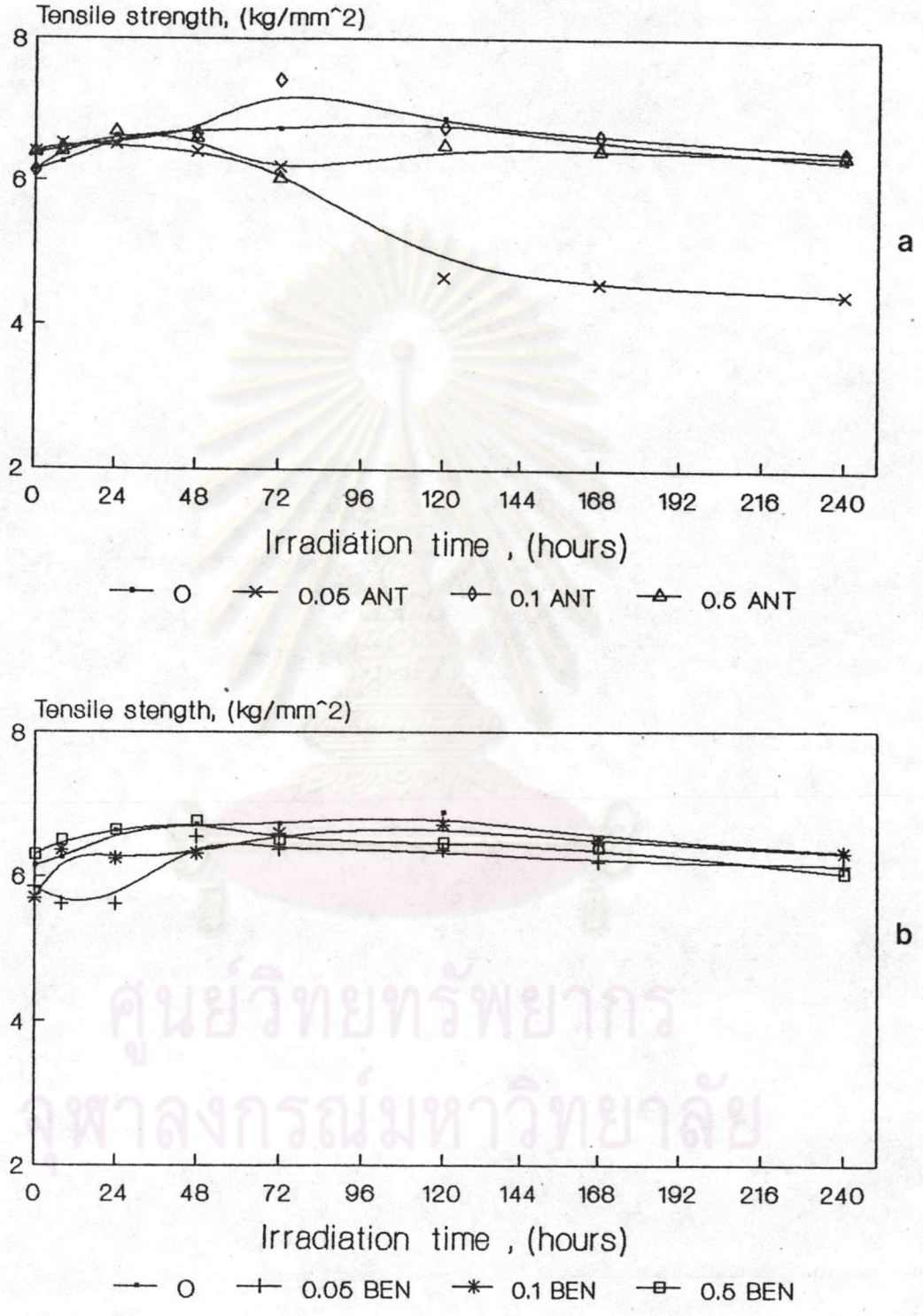


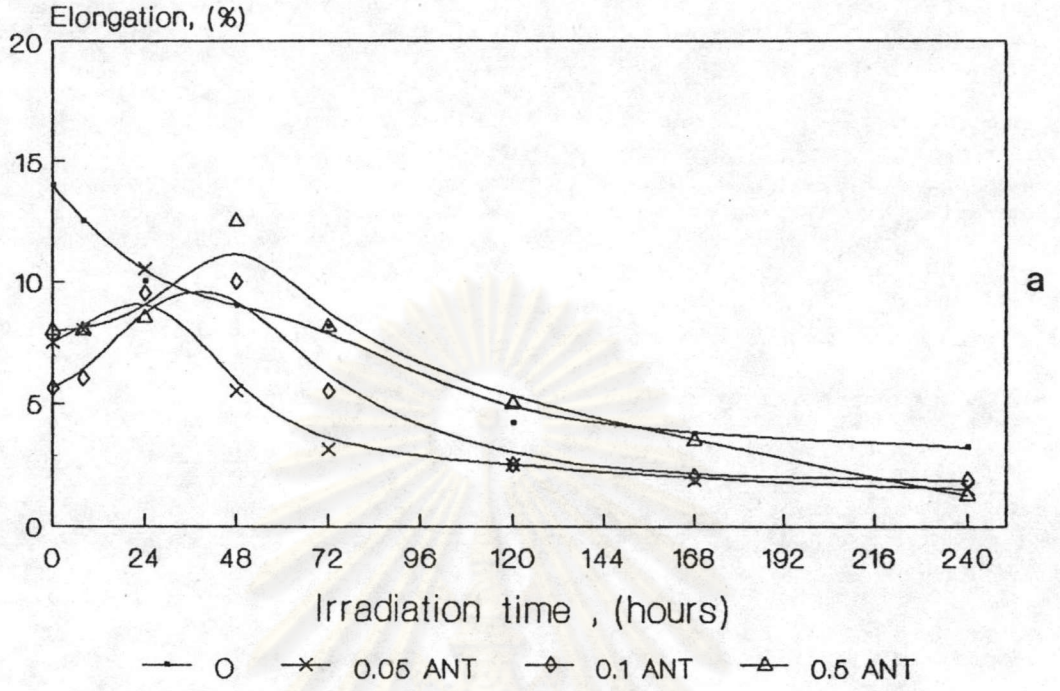
Fig. 4.11 Tensile strength of PVC samples at various concentrations of photosensitizer as a function of irradiation time. : a) anthraquinone, b) benzophenone

TABLE 4-8a The relationship of % Elongation and the irradiation time for PVC accelerating irradiated samples (photosensitizer : anthraquinone)

Irradiation time (hours)	Elongation at rupture (%)			
	0% ANT	0.05% ANT	0.1% ANT	0.5% ANT
original	14.00	7.50	5.63	8.00
8	12.50	8.00	6.00	8.00
24	10.00	10.50	9.50	8.50
48	9.00	5.50	10.00	12.50
72	8.13	3.13	5.50	8.13
120	4.17	2.50	2.50	5.00
168	3.75	1.88	2.00	3.50
240	3.00	1.50	1.88	1.80

TABLE 4-8b The relationship of % Elongation and the irradiation time for PVC accelerating irradiated samples (photosensitizer : benzopheonone)

Irradiation time (hours)	Elongation at rupture (%)			
	0% BEN	0.05% BEN	0.1% BEN	0.5% BEN
original	14.00	11.50	10.00	11.67
8	12.50	10.00	8.13	5.50
24	10.00	7.50	7.50	5.00
48	9.00	6.75	8.75	8.00
72	8.13	5.63	4.50	4.60
120	4.17	4.00	3.90	4.00
168	3.75	3.13	2.50	3.13
240	3.00	2.85	2.00	2.00



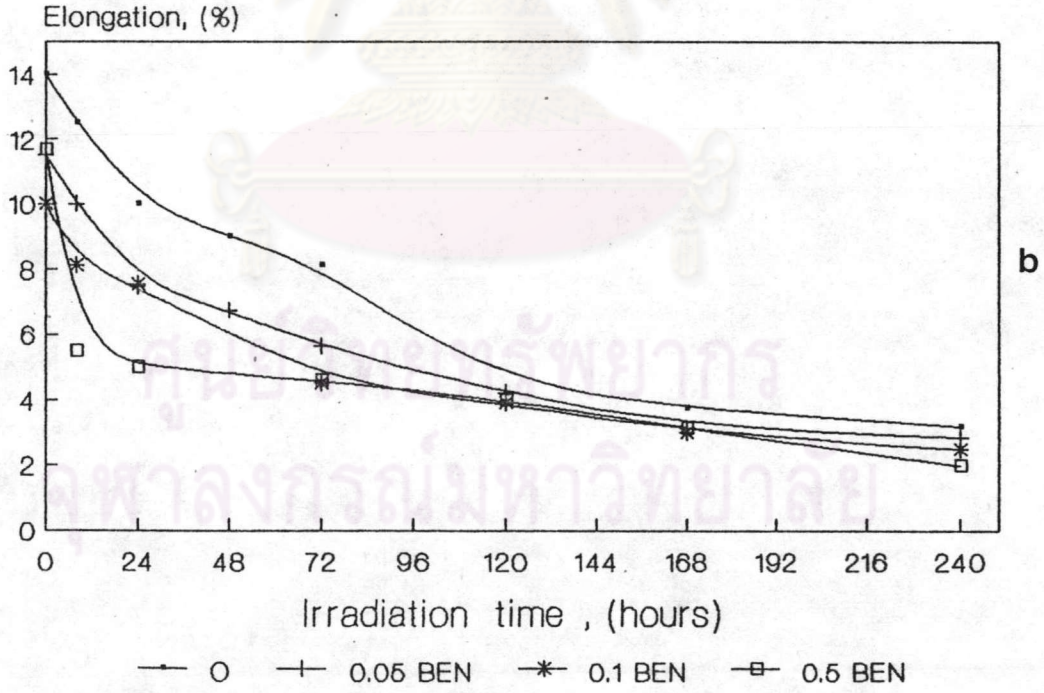


Fig. 4.12 Elongation at break of PVC samples at various concentrations of photosensitizer as a function of irradiation time. : a) anthraquinone, b) benzophenone

4.2.2 Result of molecular weight

When unsensitisized and sensitisized PVC samples are irradiated to medium pressure mercury lamp , the gel residue are formed in every samples since the begining of the irradiation. The molecular weight of the irradiated PVC samples both sensitized and unsensitized decreased gradually with the irradiation time as shown in Fig. 4.12.

Table 4-9a Relation between intrinsic viscosity [n] and average molecular weight (MW) for PVC accelerating irradiated samples (photosensitizer : anthraquinone)

Irradiation time (hours)	Intrinsic viscosity [n]	molecular weight x 10^-4
PVC-0% ANT		
original	0.7293	5.5110
8	0.7225	5.4440
24	0.7160	5.3800
48	0.7072	5.2950
72	0.6978	5.2030
120	0.6864	5.0930
168	0.6769	5.0020
240	0.6660	4.8980
PVC-0.05 ANT		
original	0.7344	5.5610
8	0.7305	5.5220
24	0.7243	5.4620
48	0.7140	5.3610
72	0.6980	5.2050
120	0.6821	5.0520
168	0.6661	4.8990
240	0.6527	4.7710
PVC-0.1 ANT		
original	0.7411	5.6270
8	0.7346	5.5630
24	0.7278	5.4960
48	0.7150	5.3710
72	0.7021	5.2450
120	0.6815	5.0460
168	0.6656	4.8940
240	0.6537	4.7800
PVC-0.5 ANT		
original	0.7840	6.0530
8	0.7426	5.6410
24	0.7361	5.5770
48	0.7266	5.4840
72	0.7091	5.3130
120	0.6840	5.0700
168	0.6619	4.8590
240	0.6412	4.6620

Table 4-9b Relation between intrinsic viscosity [n] and average molecular weight (MW) for PVC accelerating irradiated samples (photosensitizer : benzophenone)

Irradiation time (hours)	Intrinsic viscosity [n]	molecular weight x 10^-4
PVC-0% BEN		
original	0.7293	5.5110
8	0.7225	5.4440
24	0.7160	5.3800
48	0.7072	5.2950
72	0.6978	5.2030
120	0.6864	5.0930
168	0.6769	5.0020
240	0.6660	4.8980
PVC-0.05 BEN		
original	0.7321	5.5380
8	0.7270	5.4880
24	0.7203	5.4220
48	0.7139	5.3400
72	0.7031	5.2550
120	0.6881	5.1100
168	0.6768	5.0010
240	0.6629	4.8680
PVC-0.1 BEN		
original	0.7370	5.5860
8	0.7302	5.5190
24	0.7236	5.4550
48	0.7114	5.3360
72	0.7000	5.2250
120	0.6811	5.0420
168	0.6740	4.9740
240	0.6614	4.8540
PVC-0.5 BEN		
original	0.7480	5.6950
8	0.7401	5.6170
24	0.7308	5.5250
48	0.7185	5.4050
72	0.7070	5.2940
120	0.6895	5.1230
168	0.6700	4.9360
240	0.6480	4.7260

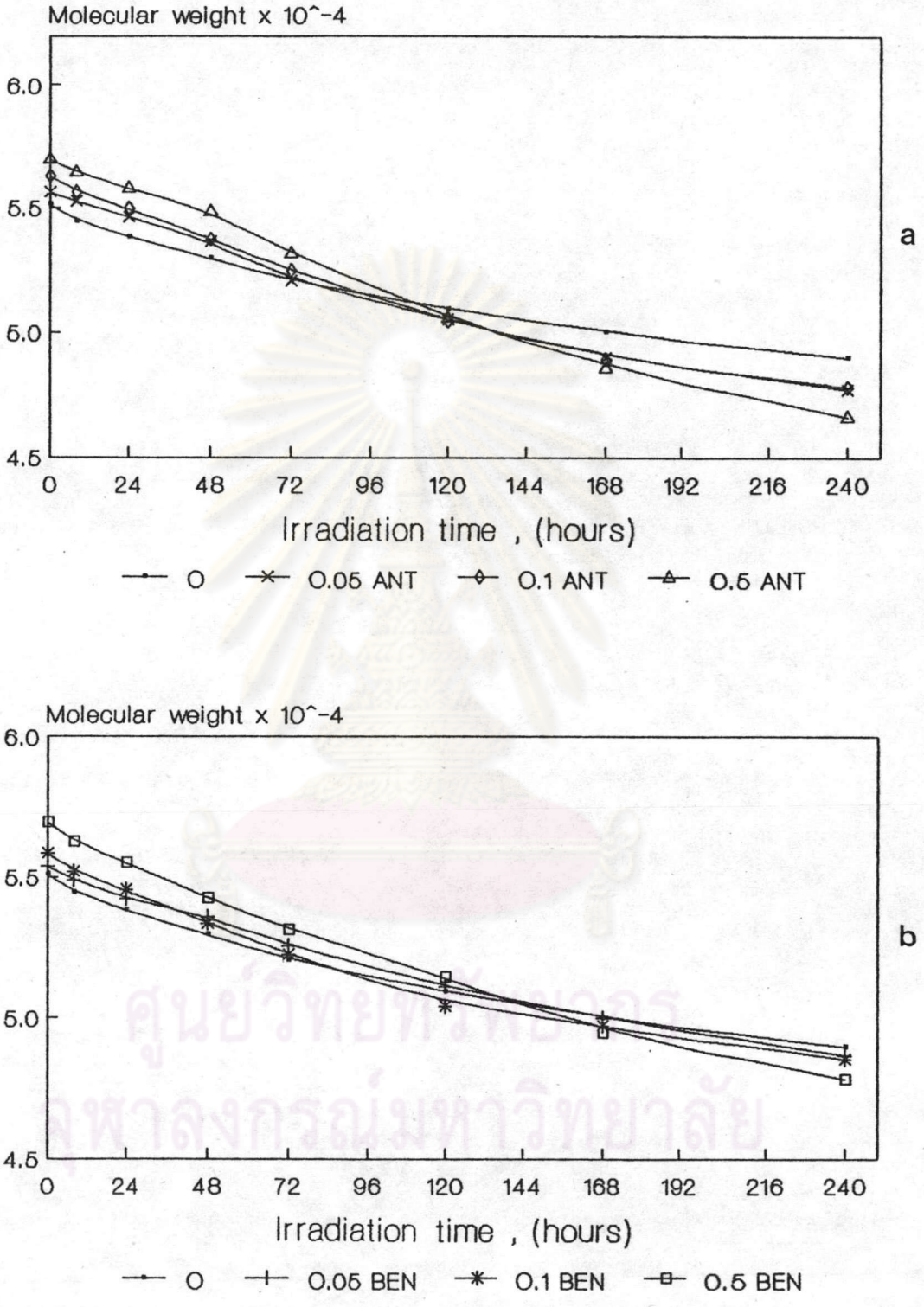


Fig. 4.13 Molecular weight traces of PVC samples at various concentrations of photosensitizer as a function of irradiation time. : a) anthraquinone, b) benzophenone

4.2.3 Result of Fourier transform infrared absorption

The FT-IR spectra of unirradiated and irradiated PVC at various concentration of photosensitizers are measured and typical spectra areshowned in Fig. 4.13. The absorption at 1735 cm^{-1} and 3460 cm^{-1} are observed with the irradiation time as shown in Fig. 4.14 - 4.15. It shown that the absorption of each interested band increase continuously with irradiation time.

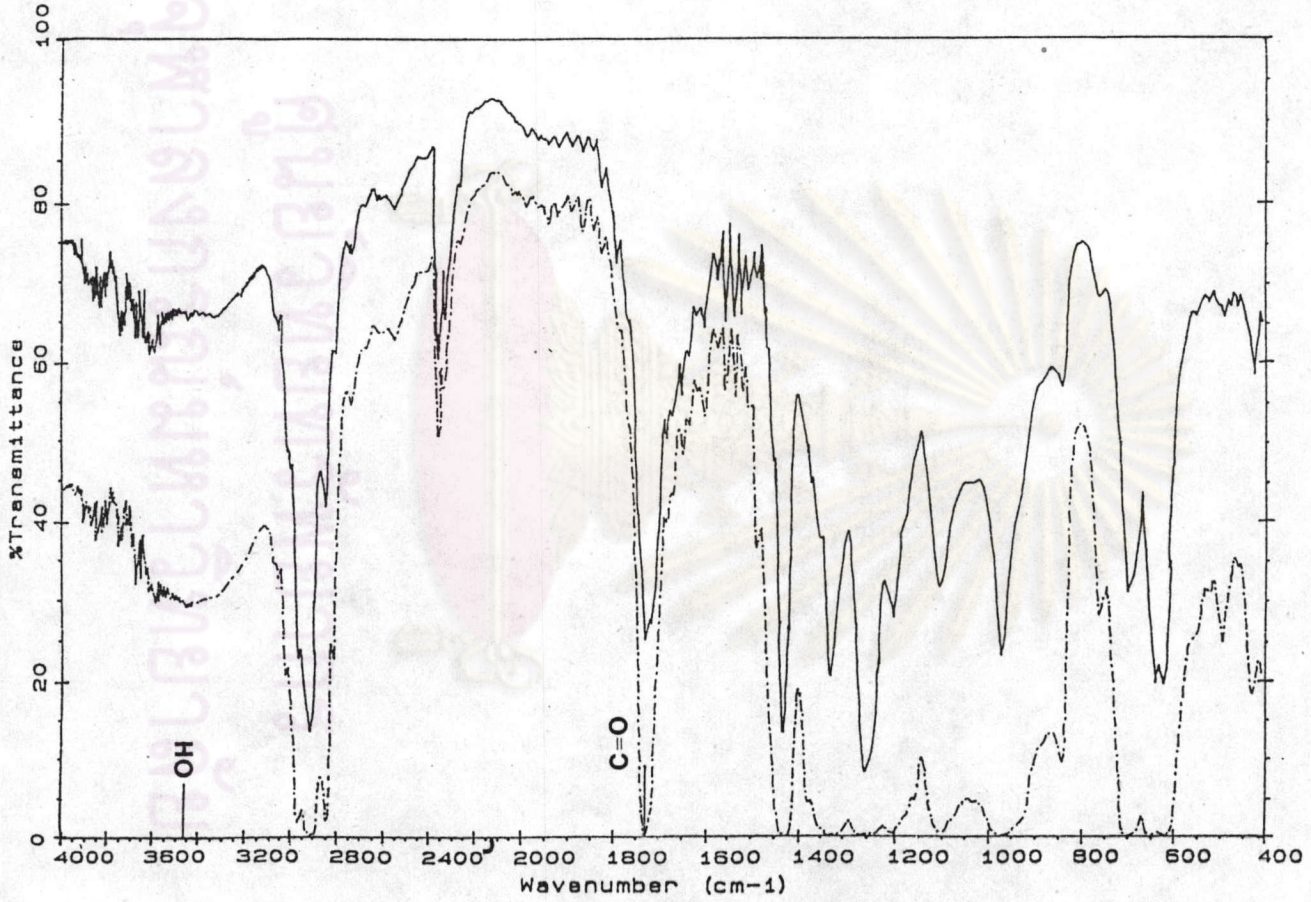


Fig. 4.13.1 FT-IR spectra of irradiated PVC samples at 0 % photosensitizer

--------- unirradiated , - - - - - irradiated for 240 hours

Table 4.10a Carbonyl Index in PVC chain of accelerating irradiated samples (sensitizer : anthraquinone)

Irradiation time	Carbonyl Index (1735 cm^-1)			
	0% A	0.05% A	0.1% A	0.5% A
original	0.780	0.825	0.876	0.899
8 hours	0.987	0.931	0.987	1.000
24 hours	1.022	1.092	1.134	1.167
48 hours	1.167	1.396	1.296	1.301
72 hours	1.424	1.431	1.406	1.520
120 hours	1.441	1.558	1.557	1.873
168 hours	1.523	1.698	1.912	2.078
240 hours	1.579	1.963	2.155	2.450

Table 4.10b Carbonyl Index in PVC chain of accelerating irradiated samples (sensitizer : benzophenone)

Irradiation time	Carbonyl Index (1735 cm^-1)			
	0% B	0.05% B	0.1% B	0.5% B
original	0.780	0.790	0.848	0.931
8 hours	0.987	0.899	0.975	1.083
24 hours	1.022	1.083	1.167	1.287
48 hours	1.167	1.134	1.250	1.494
72 hours	1.424	1.395	1.395	1.523
120 hours	1.441	1.496	1.451	1.693
168 hours	1.523	1.686	1.645	1.921
240 hours	1.579	1.873	1.970	2.259

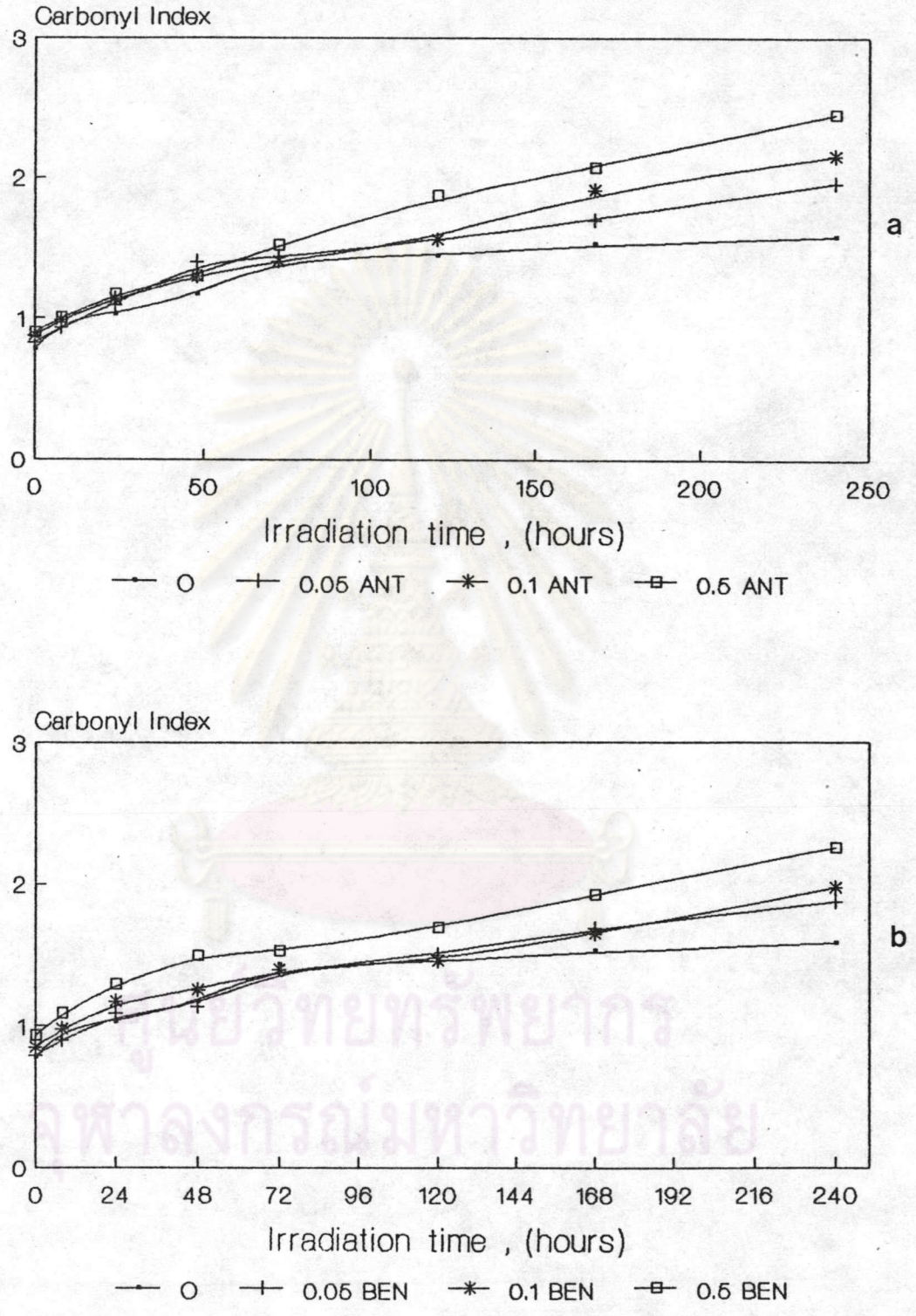


Fig. 4.15 Change of the relative FT-IR absorbance of carbonyl group in PVC chains as a function of irradiation time at various concentrations of photosensitizer. :
a) anthraquinone, b) benzophenone

Table 4.11a Hydroxyl Index in PVC chain of accelerating irradiated samples (sensitizer : anthraquinone)

Irradiation time	Hydroxyl Index (3460 cm^-1)			
	0% A	0.05% A	0.1% A	0.5% A
original	0.067	0.107	0.204	0.281
8 hours	0.076	0.132	0.238	0.287
24 hours	0.087	0.147	0.266	0.293
48 hours	0.101	0.164	0.288	0.354
72 hours	0.106	0.173	0.314	0.421
120 hours	0.134	0.197	0.336	0.457
168 hours	0.152	0.238	0.374	0.478
240 hours	0.179	0.289	0.411	0.538

Table 4.11b Hydroxyl Index in PVC chain of accelerating irradiated samples (sensitizer : benzophenone)

Irradiation time	Hydroxyl Index (3460 cm^-1)			
	0% B	0.05% B	0.1% B	0.5% B
original	0.067	0.103	0.106	0.114
8 hours	0.076	0.124	0.113	0.139
24 hours	0.087	0.131	0.150	0.202
48 hours	0.101	0.157	0.218	0.246
72 hours	0.106	0.185	0.265	0.326
120 hours	0.134	0.231	0.329	0.384
168 hours	0.152	0.268	0.357	0.432
240 hours	0.179	0.311	0.378	0.479

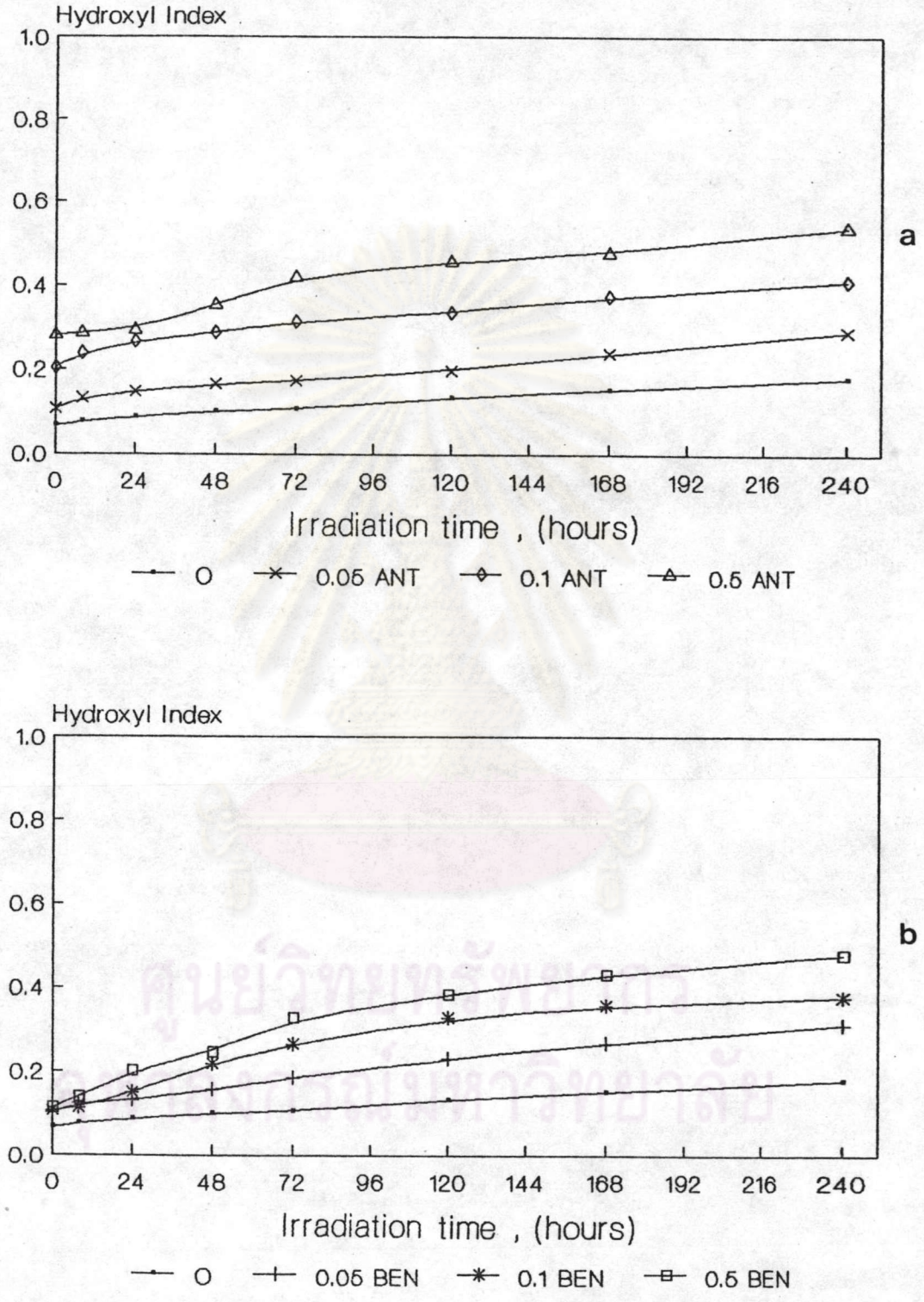


Fig. 4.16 Change of the relative FT-IR absorbance of hydroxyl group in PVC chains as a function of irradiation time at various concentrations of photosensitizer. :
a) anthraquinone, b) benzophenone

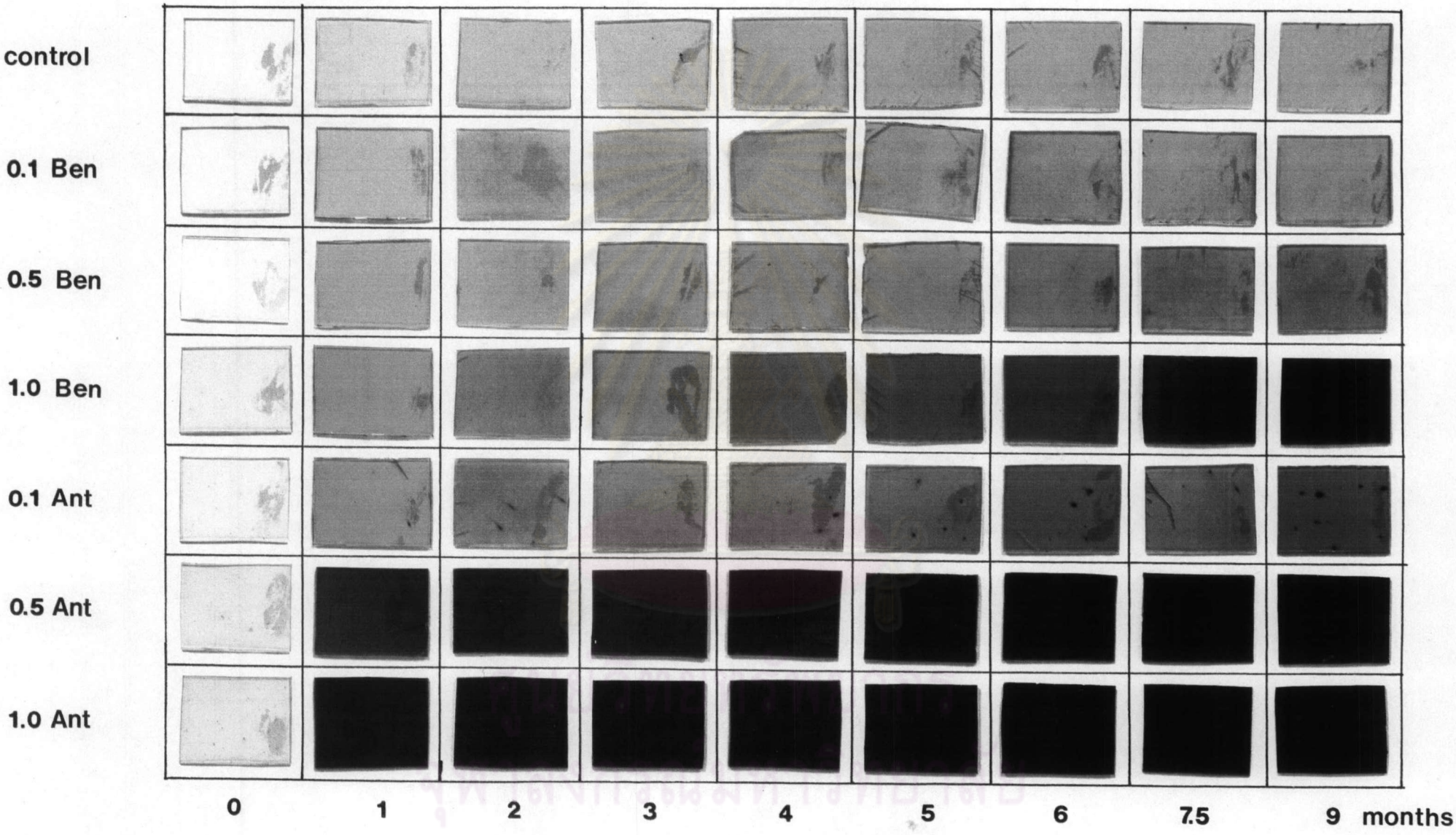


Fig. 4.17 Difference in surface changes of the outdoor exposure samples

Table 4.12 Results of visual inspection for accelerated irradiation as a function of time with various concentrations of photosensitizers (anthraquinone and benzophenone)

	Results of visual inspection	Ranks of change
CONTROL colour gloss	Yellowing after 8 hours Change slightly after 120 hours, no gloss after 240 hours exposure	7
0.05% BEN colour gloss	Yellowing after 8 hours Change slightly after 120 hours, no gloss after 240 hours exposure	6
0.1 % BEN colour gloss	Yellowing after 8 hours Change slightly after 120 hours, no gloss after 240 hours exposure	5
0.5 % BEN colour gloss	Yellowing after 8 hours and slidely brown after 168 hours of exposure Change slightly after 120 hours, no gloss after 168 hours exposure	3
0.05% ANT colour gloss	Yellowing after 8 hours exposure Change slightly after 120 hours, no gloss after 168 hours exposure	4
0.1 % ANT colour gloss	Yellowing after 8 hours and become brown after 168 hours exposure Change slightly after 120 hours, no gloss after 168 hours exposure	2
0.5 % ANT colour gloss	Yellowing after 8 hours and become brown after 72 hours exposure Change slightly after 120 hours, no gloss after 168 hours exposure	1