

Analysis of Using Ultraviolet Light to Test Color Mothball

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Abstract

Color mothball is a daily necessity in Southeast Asia. Mothball contained nearly 100% naphthalene or 100% p-dichlorobenzene. It was used to resist insects, mothproof and mildew with a special odor. In other words, the odor was thought unpleasant enough to drive animals away in repellent products. This research analyzed color mothball which was manufactured by C and N companies. The mothball was dyed with eight dyes and three essences of fragrance, respectively. The experiment of color fastness with UV-light test is to determine how much the color will fade, when it exposed to a known ultraviolet light source. In the last analysis, the experimental data from the spectrum of GC/MS described all kinds of structure on color mothball after 80 hours phototherapy treatment as shown in the content. This research reveals that color mothball can have better appearance and greater performance, to meet the requirements for customs and various applications.

Keywords

Naphthalene, Quinoline, Color, Fade, Whiteness

1. Background

Color Mothball is used to prevent insect and mothproof with a special odor and it is a daily necessity. It was sold to advanced and developed countries worldwide. However, color mothball is sold to Southeast Asia such like Malaysia, Singapore, and Indonesia in recent years. The reason is that Southeast Asia has more insect and mildew than occident. Thus, color mothball has wide market in Southeast Asia.

White mothball is very common in daily life of Europe and America. In the United States, there are nine insect repellent products containing naphthalene

that have been registered for use by the US Environmental Protection Agency. These include products intended to kill moths in airtight spaces, and to repel vertebrate pests in attics and wall void spaces, even though it is not so popular in Southeast Asia [1] [2]. Because the people in Southeast Asia prefer to use the mothball with various color and strong fragrance, the dyeing technology of mothball have been researched in these years.

This research analyzed the color mothball which was manufactured by China Steel Corporation and Japan Corporation. Let the color mothball with dyed of eight dyes (Four yellow, two red and two green) and fragrance of three essences (sunflower, ginger lily and lavender of essences) respectively. The experiment of color fastness with light test is to determine how much the color will fade when exposed to a known ultraviolet light source. In the research, we try to find a good dyestuff which owned the highest level of light fastness with Kubelka-Munk equation and color spaces of CIE Lab & CIE LCH. In the last analysis, the experiment determined of fragrance structure from Fourier transformed infrared spectroscopy (FT-IR). In addition, we researched into composition of color mothball with different company from gas chromatography—mass spectrometry (GC/MS) and described kinds of structure after 80 hours light test phototherapy treatment [3].

The mothball had the better of color fastness by FT-IR and GC/MS analyzed. That's just what we expected. In other word, this research reveals the mothball with various colors, better appearance and greater performance in order to satisfy the requirements for market and various applications [4].

2. Experimental Measurement

2.1. Kubelka-Munk Theory (K/S)

We should use K/S where K is the absorption coefficient, S is the scattering coefficient of light in the visible region (400 - 700 nm) and R_{∞} is reflectance value in maximum absorption wave length (nm) to evaluate the color strength for dye samples. In 1948, Kubelka developed numerous formulas for correlating reflectance with concentration by making scattering and surface difference corrections. It was found that the ratio of light absorption to light scattering at a given wavelength is proportional to the concentration of the dye in the sample. The relationship shown here is derived from the Kubelka-Munk equation [5] [6]:

$$\frac{K}{S} = \frac{(1 - R_{\infty})^2}{2R_{\infty}} \quad (1)$$

Figure 1 shows the light of incident is I , thickness of dx of scattering is $I^* S^* dx$ and parts of transmission is $I^* (1 - S - K)^* dx$.

2.2. Color Spaces of CIE LAB & CIE LCH

CIE L*a*b* (CIE LAB) and CIE L*C*H* (CIE LCH) are color space specified by the CIE International Commission on Illumination. It describes all the visible

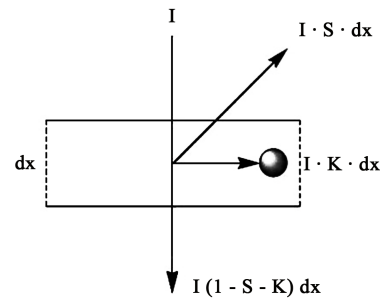


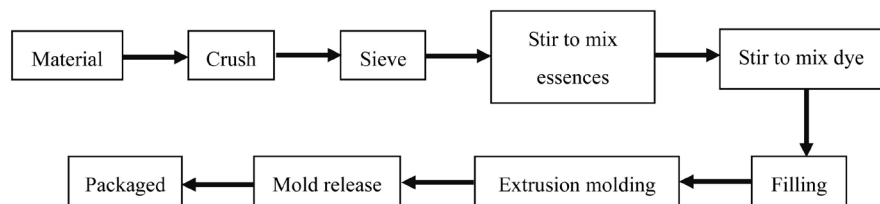
Figure 1. The relation of physical absorption and scattering.

colors visible to the human eye and was created to serve as a device independent model to be used as a reference. **Figure 2** and **Table 1** shows the three coordinates of CIE LAB represent the lightness of the color ($L^* = 0$ yields black and $L^* = 100$ indicates diffuse white; specular white may be higher), its position between red/magenta and green (a^* , negative values indicate green while positive values indicate magenta) and its position between yellow and blue (b^* , negative values indicate blue and positive values indicate yellow).

Another CIE $L^*C^*H^*$ (CIE LCH) is L^* axis represents Lightness. It ranges from $L^* = 0$ yields black and $L^* = 100$ indicates diffuse white. The C^* axis represents Chroma or “saturation”. This ranges from 0 at the centre of the circle, which is completely unsaturated (*i.e.* a neutral grey, black or white) to 100 or more at the edge of the circle for very high Chroma (saturation) or “color purity”. H^* describes the hue angle. It ranges from 0 to 360 and $H^* = 0^\circ = \text{red}/H^* = 90^\circ = \text{yellow}/H^* = 180^\circ = \text{green}/H^* = 270^\circ = \text{blue}$.

2.3. Production Process of Color Mothball

As below figure.



3. Results and Discussion

Tables 2-4 show the K/S data of color mothball for initial and after UV-light test from different color series. Color mothball was manufactured from N-company and C-company with dyed of six dyes (Two yellow, two green and two red of dye.) and three essences of fragrance (sunflower, ginger lily and lavender of essences), respectively **Figure 3** shows the difference of K/S value ($\Delta K/S$) in color mothball between initial and after UV-light test. Through the experiment, mothball after UV-light test, the color was darker than initial. We can estimate the appearance is caused by the volatility matter of color mothball. In other

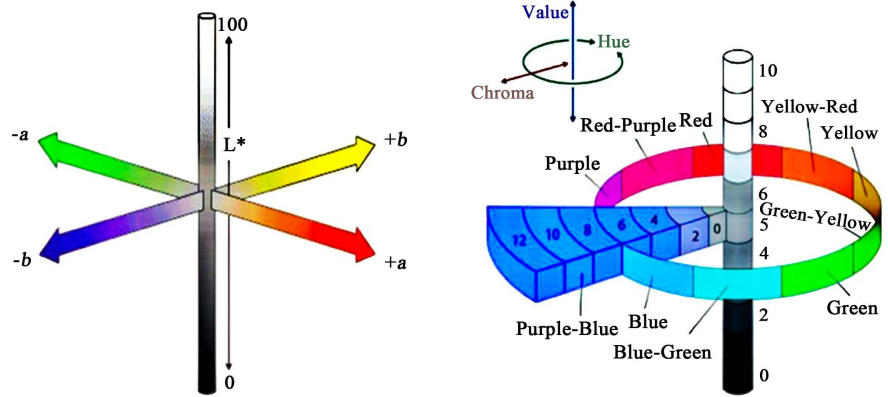


Figure 2. The CIE L*a*b* & CIE L*C*H* color model [7].

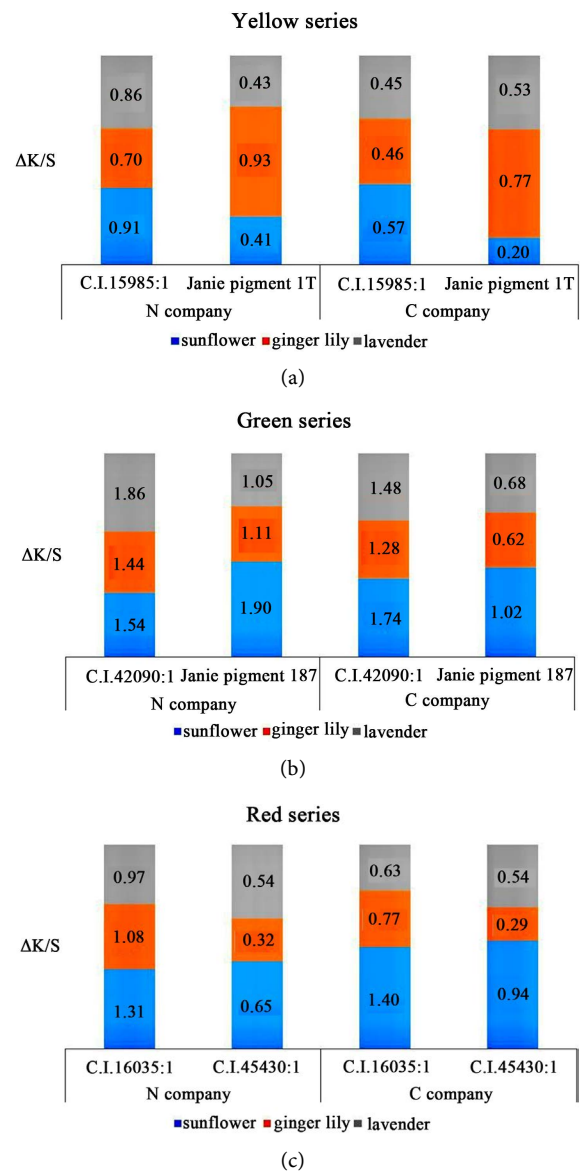


Figure 3. Comparison of the difference of K/S value in color mothball for initial and after UV-light test. (a) Yellow series (b) green series (c) red series.

Table 1. Explanation of L*, a*, b*, C*, H*.

L*	Represents a standard or sample's position on the lightness axis in either CIELAB or CIELCH color space.
a*	Represents a standard or sample's position on the green/red axis in CIELAB color space, green being in the negative direction and red being in the positive direction.
b*	Represents a standard or sample's position on the blue/yellow axis in CIELAB color space, blue being in the negative direction and yellow being in the positive direction.
C*	Represents a standard or sample's chroma value in CIELCH color space.
H*	Represents a standard or sample's hue value in CIELCH color space.

Table 2. The K/S data of color mothball for initial and after UV-light test from yellow series dye.

Essence	Color strength	Dye			
		C.I. 15985:1		Janie pigment 1T	
	Company	N	C	N	C
sunflower	(K/S) _{initial}	0.4786	0.6388	1.7955	1.2789
	(K/S) _{after}	1.3880	1.2082	2.2092	1.4772
ginger lily	(K/S) _{initial}	0.5033	0.4171	2.0213	1.3303
	(K/S) _{after}	1.1996	0.8793	2.9514	2.1019
lavender	(K/S) _{initial}	0.5429	0.4985	2.0449	1.5337
	(K/S) _{after}	1.4056	0.9438	2.4759	2.0637

Table 3. The K/S data of color mothball for initial and after UV-light test from green series dye.

Essence	Color strength	Dye			
		C.I. 42090:1		Janie pigment 187	
	Company	N	C	N	C
sunflower	(K/S) _{initial}	0.6511	0.5705	0.9479	0.7159
	(K/S) _{after}	2.1928	2.3083	2.8471	1.7404
ginger lily	(K/S) _{initial}	0.4653	0.4101	1.1214	1.0618
	(K/S) _{after}	1.9078	1.6916	2.2313	1.6828
lavender	(K/S) _{initial}	0.3454	0.3601	1.324	0.8127
	(K/S) _{after}	2.2023	1.8409	2.3691	1.4884

Table 4. The K/S data of color mothball for initial and after UV-light test from red series dye.

Essence	Color strength	Dye			
		C.I. 16035:1		C.I. 45430:1	
	Company	N	C	N	C
sunflower	(K/S) _{initial}	0.5916	0.565	0.733	0.4622
	(K/S) _{after}	1.9008	1.9687	1.3869	1.4033
ginger lily	(K/S) _{initial}	0.3362	0.3485	0.6961	0.5956
	(K/S) _{after}	1.4121	1.1147	1.0141	0.8896
lavender	(K/S) _{initial}	0.3976	0.4598	0.4244	0.4244
	(K/S) _{after}	1.3693	1.0882	0.9678	0.9678

words, unit volume of dye in color mothball is increased. Thus K/S value is increased after UV-light test.

In **Figure 3**, we can find color mothball have regularities at K/S value in dyes and essences, no matter what N or C company product. We need to rely on K/S to evaluate the color strength for dye samples. Such as color mothball use yellow dye of Janie pigment 1T with sunflower essences, green dye of Janie pigment 187 with lavender essences have better color fastness and red dye of C.I. 45430:1 with ginger lily essences have better color fastness.

From the above results, we select color mothball dyed with Janie pigment 1T of yellow series, C.I. 45430:1 of red series and Janie pigment 187 of green series. **Figure 4** shows the color mothball difference in L^* , a^* , b^* and c^* value between initial and after UV-light test. The research mainly discusses lightness (L^*), red/green values (a^*), yellow/blue values (b^*) and Chroma (C^*). As shown in **Figure 5**, we can find color mothball that have regularities at L^* , a^* , b^* and C^* value in the same dyes and essences, no matter what C or N company product. Mothball used dye of Janie pigment 1T with sunflower essences, C.I. 45430:1 with ginger lily essences and Janie pigment 187 with lavender essences have the better color fastness.

Figures 5-7 showed the fragrance of three essences (sunflower, ginger lily and lavender of essences) analyzed by using FT-IR. We could find the three essences have carboxyl structure from vibration of O-H bond at wavelength range from 3400 to 3200 cm^{-1} [8], the rotation of C=O bond at wavelength range from 1685 to 1660 cm^{-1} [9] and rotation of C-O bond at wavelength range from 1410 to 1310 cm^{-1} [10]. In addition, essences have long alkyl group and vibration of C-F bond at wavelength range from 1350 to 1140 cm^{-1} [11] [12]. **Table 5** showed variety of vibration and rotation group from Fourier transform infrared spectroscopy.

From gas chromatography–mass spectrometry (GC/MS) for N and C company product. The initial compositions of color mothball from C and N company product, as shown in **Table 6**. Because the composition of the mothballs produced by each company is different, we must discuss whether the different ingredients have an effect on the final result. In the GC/MS analyze, we could get minor constituents of 8 ppm indene, 48 ppm indole, 23 ppm quinoline and 20 ppm iso-quinoline in company C product, but those could not be found almost in N-company product. Mothball of product from N company have more thianaphthene than its in C company product. The retention time of 7.438 min. and 8.841 min. are represent as indene and indole, respectively. Color mothball of C company product have more indene and indole than N company product.

In addition, we found dark solid formed on the surface of color mothball after UV-light test. Thus, **Figure 8** shows the GC/MS chromatogram of the dark solid. These new structure were found in mothball after UV-light test. We conjecture that reason is mothball structure of dye and essences had changed by high energy of UV light.

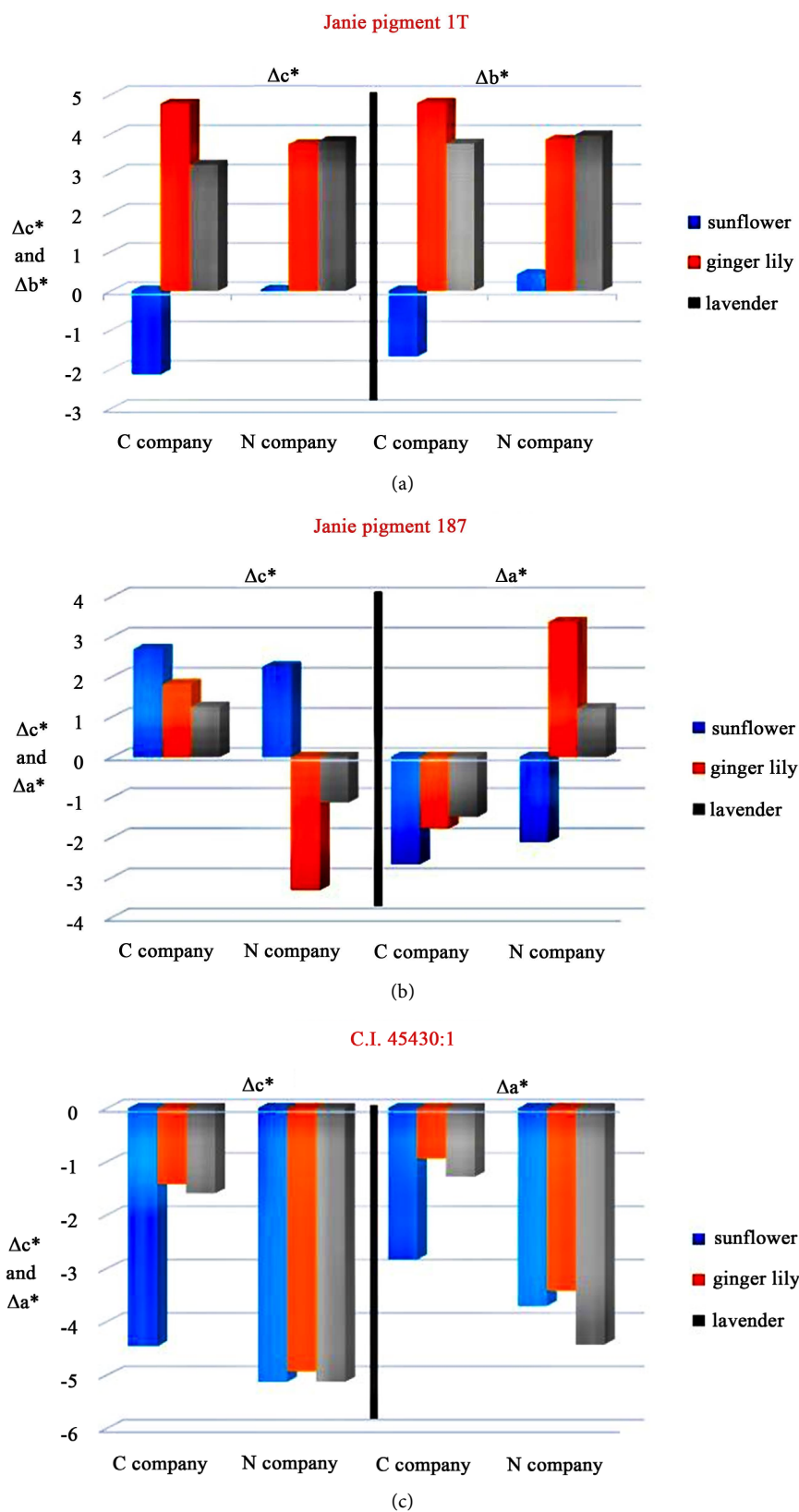


Figure 4. Comparison of the difference of L^* , a^* , b^* and c^* value in color mothball. (a) Janie Pigment 1T of yellow series (b) Janie Pigment 187 of green series (c) C.I. 45430:1 of red series.

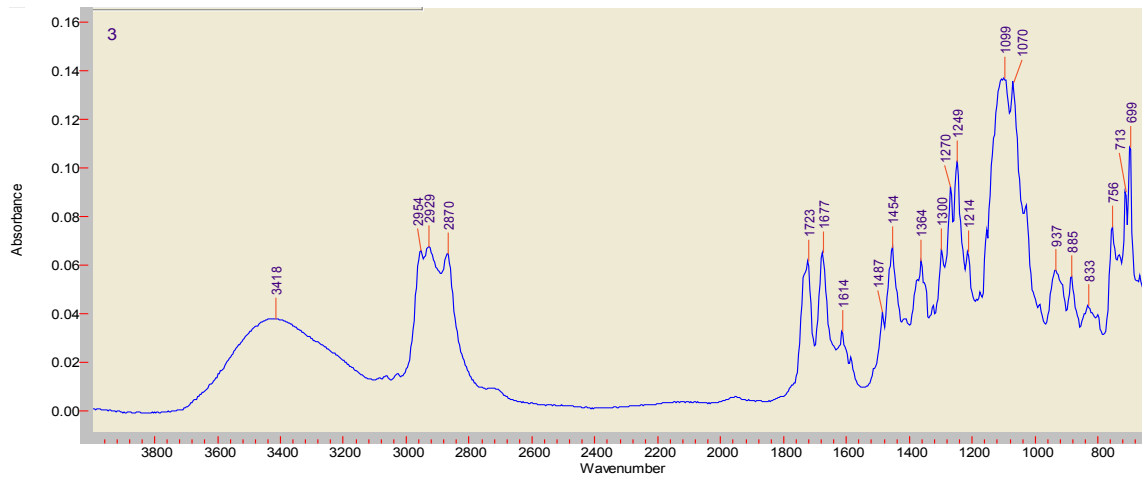


Figure 5. The fragrance of sunflower essences analyzed from Fourier transform infrared spectroscopy.

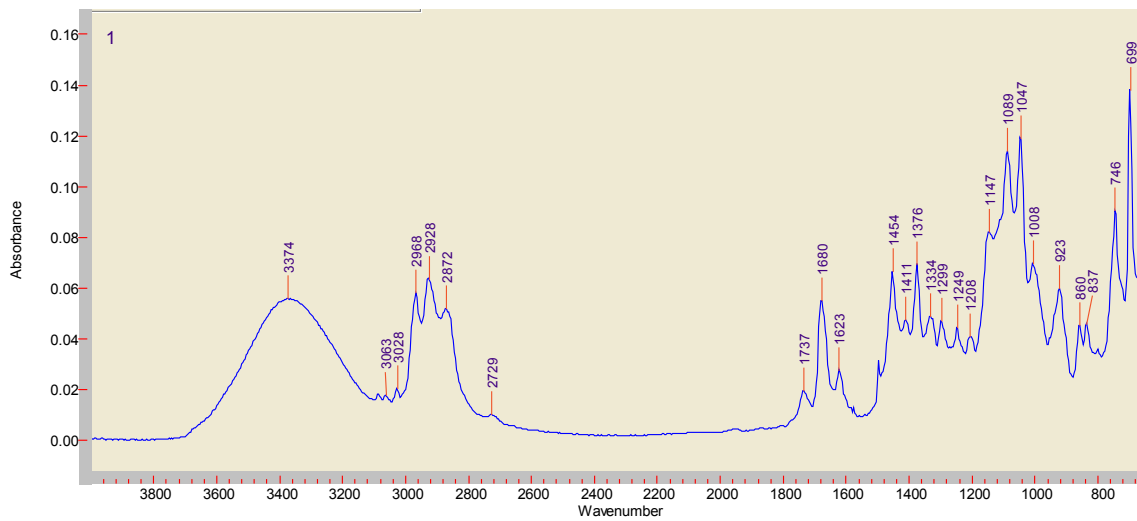


Figure 6. The fragrance of ginger lily essences analyzed from Fourier transform infrared spectroscopy.

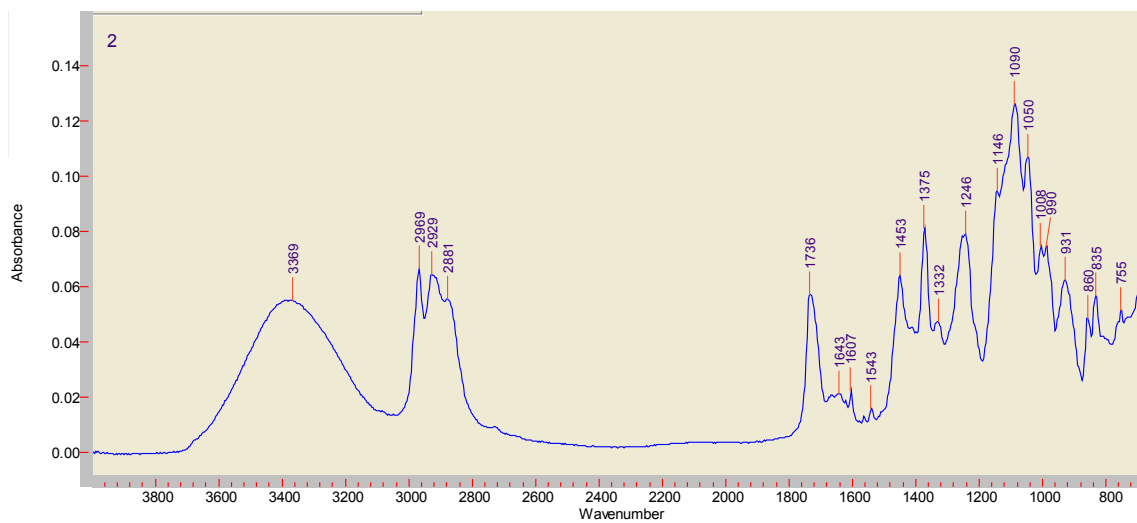


Figure 7. The fragrance of lavender essences analyzed from Fourier transform infrared spectroscopy.

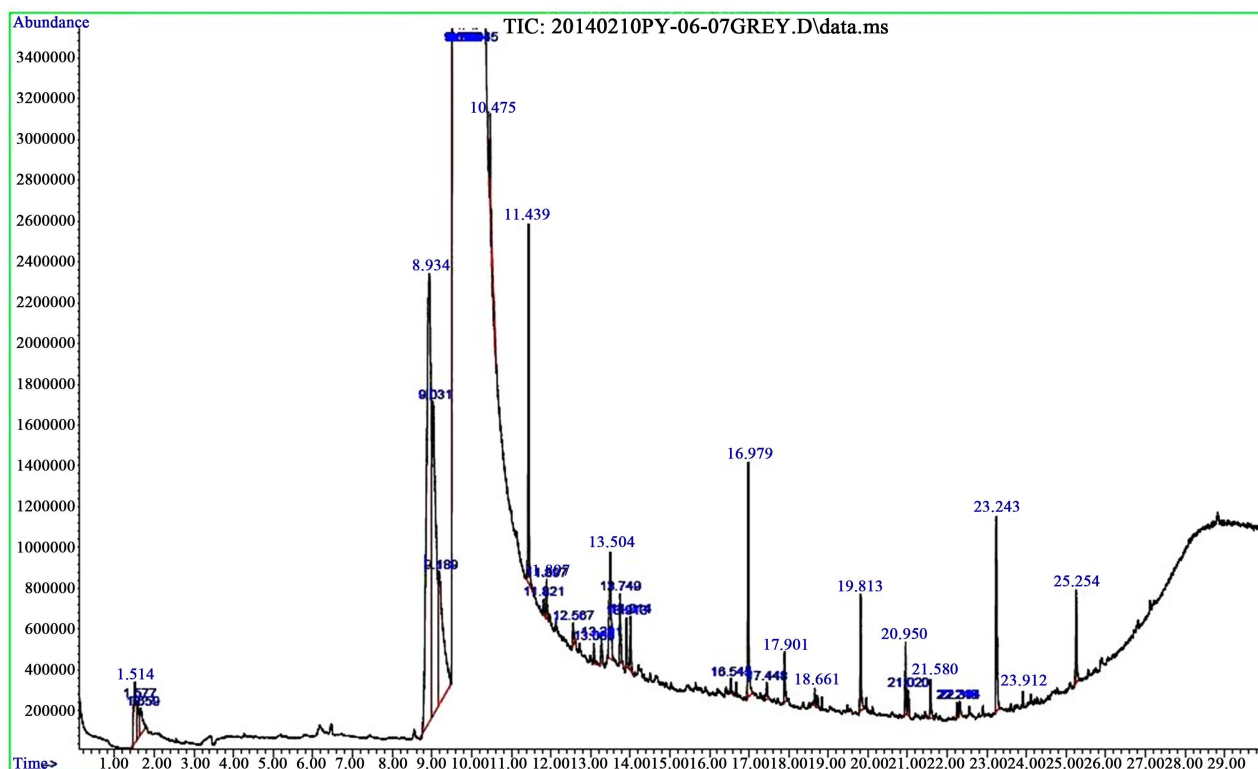


Figure 8. GC/MS chromatogram of dark solid formed on the surface of color mothball after UV-light test.

Table 5. The variety of vibration and rotation group from Fourier transform infrared spectroscopy.

Classification	Group	Bond	Rang cm^{-1}
Alkanes	R-CH ₃	C-H	2972 - 2952, 2882 - 2662, 1475 - 1435, 1380 - 1375
	C-(CH ₃) ₂	C-C	1175 - 1165, 1160 - 1135
	C-(CH ₃) ₃	C-C	1255 - 1245, 1250 - 1200
	R-C-(CH ₂) ₄ -O	C-C	742 - 734
Alkenes	CH=CH Cis	C-H, C=C	3040 - 3010, 730 - 650, 1662 - 1631
Alcohols	(R) ₃ -C-O-H	O-H, C-O	3400 - 3200, 1410 - 1310, 1210 - 1110, 1075 - 1000
Ketones	C=C-COR	C=O	1685 - 1665
	Quinones	C=O	1690 - 1660
Halogens	Ring CF ₂	C-F	1350 - 1140
Silicons	Si-O-Si, Si-O-C	Si-O-Si, Si-O-C	1100 - 1000
Sulfur	C-SO ₂ -O-C	S=O, S-O, S-C	1375 - 1335, 1195 - 1165, 1020 - 850, 830 - 690, 700 - 600

Table 6. The original compositions of mothball from N company and C company.

No.	Component	N Company	C Company
1	Naphthalene, %	99.4	99.6
2	Thianaphthene, %	0.5	0.3
3	Phenol, ppm	5.0	1.0
4	Indole, ppm	9.0	48.0
5	Quinoline, ppm	Nil.	23.0
6	Iso-quinoline, ppm	Nil.	20.0
7	Indene, ppm	Nil.	8.0
8	β -MN, ppm	Nil.	2.0
9	Unknows, ppm	9.0	6.0

Figure 9 shows the structure and properties of dark solid in mothball after UV-light test. It is possible to have environmental pollution as well as adverse human health. Therefore, the volatility gas of mothball is unpleasant and worried in commercial manufacturing. [13]

4. Conclusion

Naphthalene is a polycyclic aromatic hydrocarbon that is commonly encountered in indoor and outdoor environments. It is a component of crude oil, and it is also a product of natural combustion. A significant source of non-occupational exposures in residential settings is thought to be from the use of naphthalene-based products, particularly mothballs. Naphthalene mothballs contain above 99.4% naphthalene and else product including in thianaphthene. From the experimental studies, the mothball after UV-light test the color was darker than original. This is due to the volatility matter of color mothball. In other words, the unit volume of dye in color mothball is increased. Thus K/S value is increased after UV-light test. From the retention time of GC/MS, we can get original composition of mothball from N and C company product, and the product from C company have more indene, indole, iso-quinoline and quinoline than N company due to minor constituents. The dark solid formed on the surface of color mothball after UV-light test were found. We can estimate the appearance of mothball structure by adding dye and essences, and then observe the appearance

Peak No.	GC	GC/MS			Risk Phrases
	Retention Time	Mass (m/e)	Molecular formula	Molecular structure	
1	8.934	126.9(M ⁺) 92.0(C ₆ H ₄ NH ₂) ⁺ , 65.0(C ₂ H ₃) ⁺	C ₆ H ₆ ClN		R22 R45 R20/21/22
2	9.031	126.9(M ⁺) 92.0(C ₆ H ₄ NH ₂) ⁺ , 65.0(C ₂ H ₃) ⁺	C ₆ H ₆ ClN		R45 R48 R26/27
3	9.189	134.1(M ⁺) 108.1(C ₆ H ₄ S) ⁺ 89.1(C ₆ H ₄ CH ₂) ⁺	C ₇ H ₄ ClNO		R26 R35 R37 R42 R36/37/38
4	10.165	134.1(M ⁺) 105.1(C ₆ H ₄ CH ₂ O) ⁺ 77.1(C ₆ H ₆) ⁺	C ₈ H ₆ S		R22 R51/53
5	11.439	148.1(M ⁺) 104.1(C ₆ H ₄ CO) ⁺ 76.1(C ₆ H ₄) ⁺	C ₈ H ₄ O ₃		R22 R37/38 R41 R42/43
6	16.979	238(M ⁺) 89.0(C ₄ H ₈ O OH) ⁺ 45.0(C ₂ H ₄ OH) ⁺	C ₁₀ H ₂₂ O ₆		R36/37/38
7	17.901	278(M ⁺) 148.9(C ₆ H ₅ C ₃ H ₃ O ₂) ⁺	C ₁₆ H ₂₂ O ₄		R50/53 R62 R63
8	19.813	282(M ⁺) 89.1(C ₄ H ₈ O OH) ⁺ 45.1(C ₂ H ₄ OH) ⁺	C ₁₂ H ₂₆ O ₇		R25 R27 R43 R21/22
9	25.254	321.6(M ⁺) 249.8(C ₁₂ H ₇ Cl ₂ N ₂) ⁺ 124.9(C ₆ H ₂ ClN ₂) ⁺	C ₁₂ H ₈ Cl ₄ N ₂		R48 R48/23/24

Figure 9. The structure and properties of dark solid in mothball after UV-light test.

change by high energy of UV light. In FT-IR analysis, fragrance of three essences (sunflower, ginger lily and lavender of essences) has carboxyl structure, long alkyl group, and C-F bond. From the above experimental results, we think color mothball using dye of Janie pigment 1T with sunflower essences, C.I. 45430:1 with ginger lily essences and Janie pigment 187 with lavender essences have the better color fastness.

Conflicts of Interest

There is no conflict of interest regarding the publication of this paper.

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Statement

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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