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Investigation Activity and Data on Safety of Liquid Crystal Materials

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The safety data of the 76 liquid crystal components with CN-group, which were officially excluded from the list of 'deleterious substances' are discussed. The acute toxicity of the 496 liquid crystal components without CN-group being used in the market and classified according the terminal groups and the linkages are shown. The statement on the safety of the liquid crystal materials by the three liquid crystal material suppliers is made.

Keywords: liquid crystal nitriles; acute toxicity; mutagenicity; LD50; Ames test

BACKGROUND OF LIQUID CRYSTAL MATERIALS

Liquid crystal displays (LCDs) are nowadays widely used in electric and electronic products, such as laptop and notebook computers, PC monitors and cellular phones. While the quantity of the liquid crystal materials in one unit of LCD is quite small because of about 5 μ m of thin cell thickness, the production of liquid crystal materials is increasing with the recent market growth of LCDs. The market of liquid crystal materials in

worldwide is estimated about 16 tons in 1992, 27 tons in 1995 and 40 tons in 1998. The liquid crystal materials used in LCDs are liquid crystal mixtures consisting of typically 10 to 25 liquid crystal components. Each component is a chemical substance. More than 1,000 liquid crystal components are used for the design of liquid crystal mixtures to meet the requirement and more than 10, 000 liquid crystal mixtures were marketed.

PRODUCTION OF LIQUID CRYSTAL COMPONENTS

The liquid crystal components in 1997 are classified under the production quantity in Table 1. There is no component of which production exceeds 1,000 kg and the 627 in the 715 components are 10 to 100 kg of production. Only 5 components exceed 500 kg of production.

TABLE 1 Production of liquid crystal components in 1997 classified under the quantity

Production	Components
$<$100 kg	627
100$\sim$500 kg	83
500$\sim$1,000 kg	5
$>$1,000 kg	0
Total	715

Figure 1 shows the examples of production change of some liquid crystal components for 10 years from 1988 to 1997. The production of component B increases and reaches about 240 kg of the peak in 1995, and after that it decreases rapidly. There are some cases that the liquid crystal components appear and disappear in the market with the change of requirements. The production of component A increases from 1992 and shows a constant increase until 1997. On the other hand, there are many liquid crystal components which do not reach 50 kg per a year of

production like component C and component D.

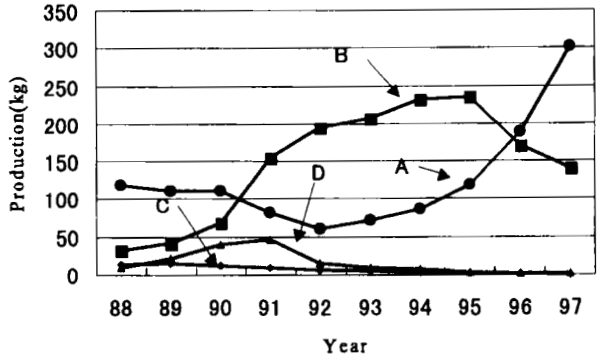


FIGURE 1 Production change of some liquid crystal components

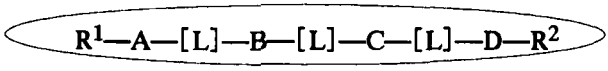
RELATING LAWS OR REGULATIONS TO CONTROL CHEMICAL SUBSTANCES

As a liquid crystal component is a chemical substance, there are some laws or regulations to control chemical substances relating to the liquid crystal components. In Japan, (1) Law Concerning the Examination and Regulation of Manufacture, etc., of Chemical Substances (Chemical Substances Control Law; MITI Law), (2) Poisonous and Deleterious Substances Control Law (Law No.303), and (3) Industrial Safety and Health Law relate to the manufacture, import and use of the liquid crystal components. The chronic toxicity should be examined for a new chemical substance not being listed in Existing Chemicals beyond 1,000 kg of manufacture and/or import under the MITI Law (1). The chronic toxicity of some liquid crystal components being close to 1,000 kg of production has been under examination. The acute toxicity (oral) LD50 and so on relate to the Law No. 303 (2). Ames test for mutagenicity should be examined for more than 100 kg of production in the place of

employment.

LIQUID CRYSTAL COMPONENTS WITH CN-GROUP

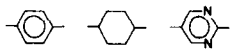
General representation of practical liquid crystal components is shown in Figure 2. By using CN-group with strong electron attraction (μ = - 4.05) as a terminal group, the liquid crystal components with large positive dielectric anisotropy, which enables the low voltage driving of LCDs, have been developed. Therefore, the liquid crystal components with CN-group are requisite for TN- and STN-LCDs.



R^1, R^2 : Terminal groups

Alkyl, Alkenyl, Alkoxy, CN, F, Cl, OCF_3

A, B, C, D : Rings (2~4)



L : Linkage groups

single bond, -COO-, -C≡C-, $-CH_2CH_2-$

FIGURE 2 General representation of practical liquid crystal components

The liquid crystal components with CN-group (nitrile group) have been classified in 'Organic Cyanides' and therefore – seen as deleterious substances – came under the Law No.303. From the viewpoint of chemical reaction, the benzonitrile derivatives do not generate toxic cyanide ions in water. We measured cyanide ions after water treatment of two mixtures of liquid crystal benzonitriles. Figure 3 shows the compositions of the samples. Sample A is a mixture of Biphenyls and

sample B is a mixture of Phenylcyclohexanes (PCHs). The test was conducted according to the Waste Disposal and Cleansing Law. After 50 ml of each sample in 500 ml of water was shaken for 6 hours at room temperature and separated by decantation and filtration, the cyanide ions in water layer were measured by colorimetric methods. For both samples, cyanide ions were not detected and the concentration was below 0.01 mg/l which is the guideline value of no hazardous waste.

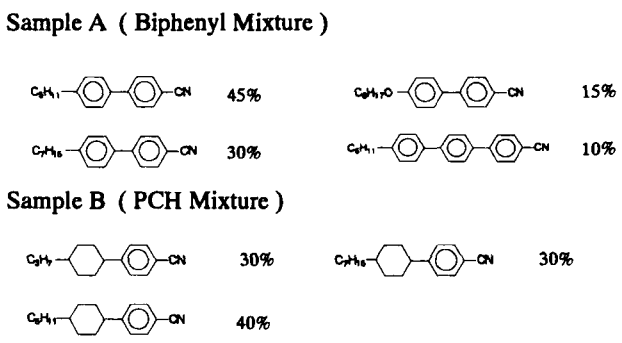


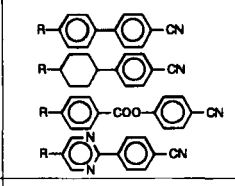
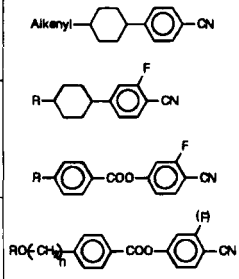
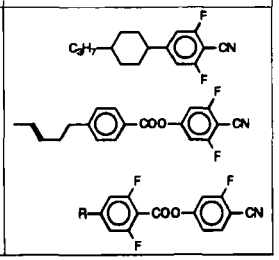
FIGURE 3 Compositions of sample A and sample B

EXCLUSION FROM 'DELETERIOUS SUBSTANCES'

We have been investigating the safety and toxicity of liquid crystal nitriles in order to prove that they can be excluded from the list of 'deleterious substances'. The acute toxicity (oral) LD50 of each liquid crystal component, of which guideline is more than 300 mg/kg, was examined. The skin irritation test was added from 1994 and the guideline is less irritant than phenol. The acute inhalation (mist) LC50 was added further from 1999 and the guideline is more than 1.0 mg/l. The history of exclusion from 'deleterious substances' is shown in Table 2. Biphenyls, PCHs, Esters and Pyrimidines, which are familiar and very important as liquid crystal components with strong positive dielectric anisotropy, were

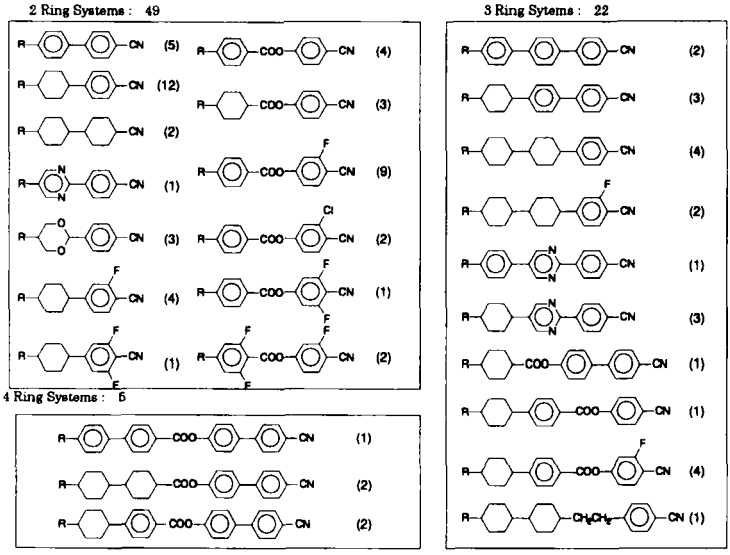
excluded in 1980 including the homologues with a different alkyl chain length. The 13 series of 26 liquid crystal components in 1988, the 15 series of 26 liquid crystal components in 1991, and the 3 series of 6 liquid crystal components in 1994, such as Alkenyl-PCHs, laterally fluorinated PCHs or Esters, and Alkoxyalkyl-Esters, which are useful for STN-LCDs, were excluded. Moreover, the 3 series of 4 components of multi-fluorinated PCH and Esters were excluded in 1999.

TABLE 2 History of exclusion from "Deleterious Substances"

Year	Excluded Liquid Crystal Components	Examples
1980	8 Series Including Homologues (14 Components)	
1988	13 Series 26 Components	
1991	15 Series 26 Components	
1994	3 Series 6 Components	
1999	3 Series 4 Components	

All of the 76 liquid crystal components being applied to the Ministry of Welfare, which are listed in Table 3 in general formula, were excluded after being examined the safety data. The 76 liquid crystal components consists of the 49 components of 2 ring systems, the 22 components of 3 ring systems and the 5 components of 4 ring systems. The number in a parenthesis in Table 3 is number of components of the formula.

TABLE 3 76 liquid crystal components with CN-group excluded from 'Deleterious Substances'

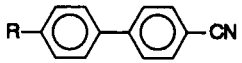


SAFETY DATA OF LIQUID CRYSTAL COMPONENTS WITH CN-GROUP

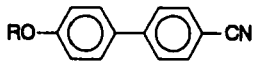
The acute toxicity (oral) LD50 of the excluded 76 liquid crystal components are listed in Table 4.

TABLE 4 Acute toxicity (oral) LD50 of excluded 76 liquid crystal components

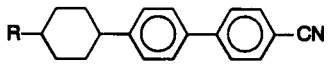
1)Biphenils



R	LD50 (mg/kg)
C_5H_{11}-	> 4,000
C_7H_{15}-	> 4,000

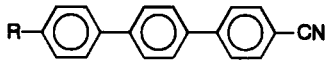


RO	LD50 (mg/kg)
$C_5H_{11}O$-	2,750
$C_7H_{15}O$-	16,000
C_2H_5-O-C_2H_4-O-	> 2,000

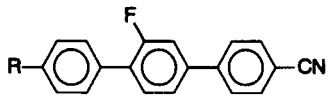


R	LD50 (mg/kg)
C_5H_{11}-	> 10,000
CH_2 = CH- C_5H_6-	> 1,000
CH_2 = CH- C_2H_4-	> 1,000

2) Terphenyls



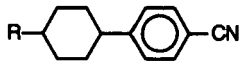
R	LD50 (mg/kg)
C_5H_{11}-	> 4,000



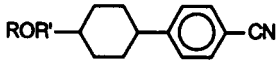
R	LD50 (mg/kg)
C_5H_7-	> 5,000

TABLE 4 Acute toxicity (oral) LD50 of excluded 76 liquid crystal components(continued)

3) Phenylcyclohexanes

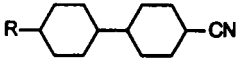


R	LD50 (mg/kg)
C_3H_7-	> 2,348
C_5H_{11}-	> 3,547
C_7H_{14}-	> 4,432
CH_2 = CH-	1,282
CH_3- CH = CH-	> 2,000
C_3H_7- CH = CH-	> 2,000
CH_2 = CH- C_2H_4-	> 2,500
CH_2 = CH- C_3H_6-	> 5 ml/kg
CH_3- CH = CH- C_2H_4-	> 2,000

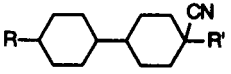


ROR'	LD50 (mg/kg)
CH_3OCH_2-	3,200
$C_2H_5OCH_2$-	> 2,000
$CH_3OC_3H_6$-	> 2,000

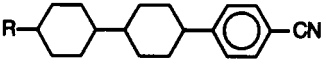
4) Bicyclohexanes



R	LD50 (mg/kg)
C_2H_5-	4,889



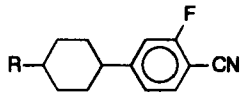
R	LD50 (mg/kg)
C_4H_9-	> 5,000



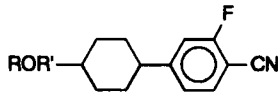
R	LD50 (mg/kg)
C_2H_5-	> 2,000
C_3H_7-	> 7,430
C_4H_9-	> 2,000
C_5H_{11}-	> 2,000

TABLE 4 Acute toxicity (oral) LD50 of excluded 76 liquid crystal components (continued)

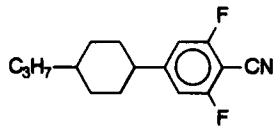
5) Fluorinated Phenylcyclohexanes



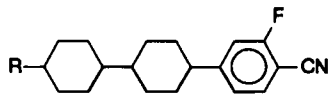
R	LD50 (mg/kg)
C_2H_5-	> 2,000
C_3H_7-	15,000
C_5H_{11}-	9,100



R	LD50 (mg/kg)
CH_3O-$(CH_2)_3$-	2,492

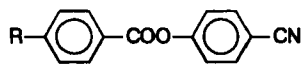


R	LD50 (mg/kg)
C_3H_7-	> 2,000



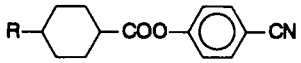
R =	LD50 (mg/kg)
C_2H_5-	> 7,920
C_3H_7-	> 10,000

6) Esters (2Ring)



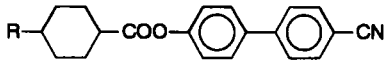
R	LD50 (mg/kg)
C_4H_9-	6,530
C_5H_{11}-	8,760
C_6H_{13}-	5,640
C_2H_5-$CH(CH_3)$-CH_2O-	> 7,000

TABLE 4 Acute toxicity (oral) LD50 of excluded 76 liquid crystal components(continued)

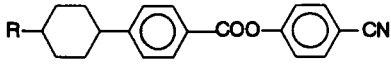


R	LD50 (mg/kg)
C_3H_7-	2,200
C_4H_9-	5,390
C_5H_{11}-	> 8,000

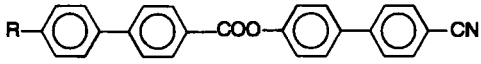
7) Esters (3 Ring, 4 Ring)



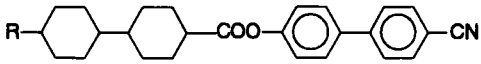
R	LD50 (mg/kg)
C_3H_8-	> 5,000



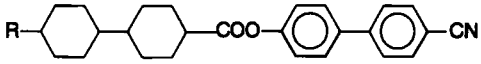
R	LD50 (mg/kg)
C_5H_{11}-	> 5,000



R	LD50 (mg/kg)
C_7H_{16}-	> 5,000



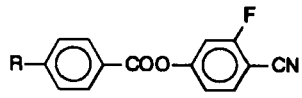
R =	LD50 (mg/kg)
C_3H_7-	> 2,000
C_5H_{11}-	> 2,000



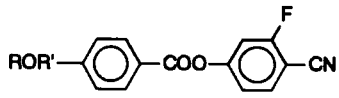
R =	LD50 (mg/kg)
C_3H_7-	> 8,280
C_5H_{11}-	> 7,000

TABLE 4 Acute toxicity (oral) LD50 of excluded 76 liquid crystal components(continued)

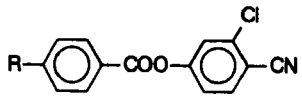
8) Halogenated Esters (2 Ring)



R	LD50 (mg/kg)
C_2H_5-	12,000
C_3H_7-	10 ,700
C_4H_9-	> 2,000
C_5H_{11}-	> 2,000
C_7H_{15}-	> 5,000

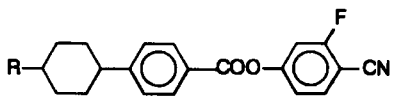


ROR'	LD50 (mg/kg)
C_2H_5-OCH_2-	> 2,000
C_3H_7-OCH_2-	> 2,000
C_4H_9-OCH_2-	> 2,000
C_5H_{11}-OCH_2-	> 2,000



R =	LD50 (mg/kg)
C_2H_5-	> 2,000
C_3H_7-	> 2,000

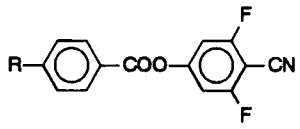
9) Fluorinated Esters (3 Ring)



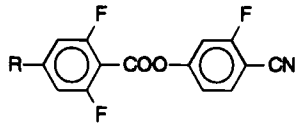
R	LD50 (mg/kg)
C_2H_5-	> 12,000
C_3H_7-	> 12,000
C_4H_9-	> 2,000
C_5H_{11}-	> 5,000

TABLE 4 Acute toxicity (oral) LD50 of excluded 76 liquid crystal components(continued)

10) Multi-Fluorinated Esters

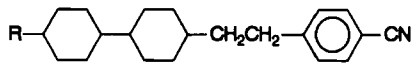


R	LD50 (mg/kg)
CH_3-CH = CH-C_2H_4-	> 4,000



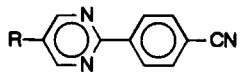
R	LD50 (mg/kg)
C_4H_9-	> 2,000
C_6H_{11}-	> 2,000

11) Ethylenes

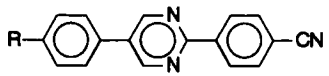


R	LD50 (mg/kg)
C_3H_7-	> 5,000

12) Hetero Rings

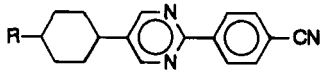


R	LD50 (mg/kg)
C_7H_{15}-	> 4,000

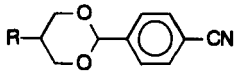


R	LD50 (mg/kg)
C_4H_9-	> 4,000

TABLE 4 Acute toxicity (oral) LD50 of excluded 76 liquid crystal components(continued)



R	LD50 (mg/kg)
C_2H_5-	1,480
C_6H_{11}-	> 2,000
C_7H_{15}-	> 2,000



R	LD50 (mg/kg)
C_3H_7-	> 5,000
C_4H_9-	> 5,000
C_5H_{11}-	> 5,000

The LD50 of the liquid crystal components can be compared with that of the following well known chemical substances; 70 mg/kg of nicotine in cigarette, 725 mg of creosote in digestive, 3,310 mg/kg of acetic acid in vinegar and 7,000 mg/kg of ethanol in wine. All LD50 of the 76 liquid crystal components with CN-group are far larger than 300 mg/kg of the guideline and are more than 1,000 mg/kg, in which the LD50 of the 72 liquid crystal components are more than 2,000 mg/kg. All of the examined 10 components have no effect or mild for skin irritation, and much less irritant than phenol. The acute inhalation (mist) LC50 of the examined 4 components are more than 1.0 mg/l of the guideline. These results show that the 76 liquid crystal components cannot be categorized as deleterious substances. Moreover, all Ames tests for the 76 liquid crystal components show negative.

SAFETY DATA OF LIQUID CRYSTAL COMPONENTS WITHOUT CN-GROUP

There are also a lot of liquid crystal components without CN-group.

Non-polar components with low viscosity are used to meet quick response and the fluorinated or chlorinated liquid crystal components are requisite for active matrix (AM) LCDs in order to achieve the compatibility of high voltage holding ratio and low driving voltage because CN-group is not applicable to the components for the active matrix TN-LCDs. Table 5 shows the results of the LD50 of the liquid crystal components without CN-group being used in the market and classified according to the terminal group and the linkage.

TABLE 5 Safety data of the 464 liquid crystal components without CN-group being used in the Market

Terminal Group / Linkage	Halogenated	Results		Others	Results	
Single Bond	139	1	130	82	1	79
		2	9		2	3
		3	0		3	0
- COO -	57	1	54	70	1	66
		2	3		2	4
		3	0		3	0
- C≡C -	16	1	16	29	1	28
		2	0		2	1
		3	0		3	0
- CH_2CH_2 -	36	1	35	20	1	20
		2	1		2	0
		3	0		3	0
Others	1	1	1	14	1	13
		2	0		2	1
		3	0		3	0
Total	249	1	236	215	1	206
		2	13		2	9
		3	0		3	0

Results 1 : LD50 > 2000 mg / Kg
2 : 300 < LD50 ≦ 2000 mg / Kg
3 : 30 < LD50 ≦ 300 mg / Kg

The LD50 of the 236 components in the 249 the liquid crystal components with halogenated terminal group and the 206 components in the 215 liquid crystal components with other terminal groups are more than

2,000 mg/kg. There is no liquid crystal component of which LD50 is below 300 mg/kg of the guide line of the deleterious substances. Moreover, all of the 464 liquid crystal components without CN-group show negative for Ames tests.

STATEMENT ON SAFETY OF LIQUID CRYSTAL MATERIALS

Based on the above safety data and the results of our current investigation, we make a following statement on the safety of liquid crystal materials;

We, the three liquid crystal material suppliers: Merck, Chisso and Dainippon Ink maintain the safety of our products, both towards the users and the environment. Therefore, we carry out intensive toxicological investigations and do not introduce the toxic or mutagenic liquid crystal materials into the market. Moreover, we investigate the ecotoxicological properties of our liquid crystal materials in compliance with legal regulations and as precautionary measures according to the principles of "Responsible Care" and "Product Stewardship".