PRELIMINARY STUDY OF SELECTED POTENTIAL ENVIRONMENTAL CONTAMINANTS – OPTICAL BRIGHTENERS, METHYL CHLOROFORM, TRICHLOROETHYLENE, TETRACHLOROETHYLENE, ION EXCHANGE RESINS

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Office of Toxic Substances
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Final Report

PRELIMINARY STUDY OF SELECTED POTENTIAL ENVIRONMENTAL CONTAMINANTS

OPTICAL BRIGHTENERS
METHYL CHLOROFORM
TRICHLOROETHYLENE
TETRACHLOROETHYLENE
ION EXCHANGE RESINS

Contract No. 68-01-2657

Project Officer
Frank D. Kover

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Washington, D.C. 20460

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NOTICE

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OPTICAL BRIGHTENERS: Summary and Conclusions

The "optical brighteners" constitute a unique class of chemicals, not only because of their wide structural variety but also because of their wide application range.

In recent years, optical brighteners have become one of the more important components of laundering products in the United States. Millions of pounds are used yearly for this purpose. Virtually all clothing contains brighteners; they are used extensively for the mass whitening of synthetic polymer fibers, during which the optical brightener is added to the spinning solution or melt. They are also used in the finishing of textiles, including "wash-wear" cottons, where they are applied to the fabric along with a finishing agent. In paper manufacture, the brighteners can be applied to the pulp in the dipping process or during the coating operation. Most of the vast numbers of articles which are manufactured from plastics contain brighteners, including wrappers and containers for foodstuffs.

Although the production of optical brighteners in the United States has declined somewhat, this cannot be taken as an indication of the prevalence of these agents without reference to import statistics: available figures show that approximately 2,000,000 pounds of brighteners were imported in 1972. These import figures are broken down to the amount of each brightener by trade name. No such breakdown was found for the brighteners which are manufactured in the United States.

Identification of the individual structures of the molecules which are employed as brightening agents has become increasingly difficult because of their growing numbers and tremendous structural varieties. Each agent,

of course, has a characteristic spectral-absorption curve of minimum transmittance or maximum absorption. Reliable identification, however, would depend on a detailed examination by chromatography, absorption spectroscopy, and comparison of the infrared spectra to determine the parent structure and the substituents.

Nothing is reported on the fate of these compounds when their substrates decompose, i.e., deterioration from use or gradual decomposition after being discarded, or following incineration of the substrate. They certainly have a direct route into the water supply, being carried in the effluent from manufacturing plants and in household laundry waste water. The stilbenedisulfonic acid salts are water soluble when released as the free molecule (not attached to a substrate) into aquatic systems.

Considering the inertness of the optical brighteners towards other chemicals which they contact during application, and their stability under rigorous processing conditions, it would seem that they should remain stable in the environment. Those brighteners which are incorporated into enzyme-containing detergent formulations would probably resist biodegradibility becuase of their enzyme-stability. This would certainly raise the question of bioaccumulation, on which no specific studies under natural conditions (accumulation in fish, for instance) have been reported. The few tissue-affinity studies which have been published report a rapid excretion of the brighteners into the bile or the urine. Long-term studies showed no changes in the organs of the test animals. These results, of course, are valid only for those compounds which were selected for the studies.

All studies reported in the literature on the toxicity of the optical brighteners toward humans and the lower animals gave negative results. The

studies on animal reporduction, including teratogenicity and mutagenicity studies, also gave negative results.

One specious report of the carcinogenic interaction of the optical brighteners and ultraviolet light appeared in the recent literature and reported positive results. However, this work has been highly criticized because it was conducted under unrealistic conditions and thus had no practical value. The authors of this report have conceded to their critics and have announced that further work is in progress. All other studies on carcinogenesis have reported negative results.

In summary, it would seem that introduction into environmental waters would be the most probable source of pollution by the optical brightening agents. There are no data in the literature reporting on the fat-solubility of any brightener molecules. This property would have bearing on bioaccumulation. While these compounds may be chemically inert *in vitro*, no conclusions can be drawn from the information in the literature as to what biological activity they might exhibit if they gained entrance into human systems to any extent.

Optical Brighteners

1. PROPERTIES AND USES

The literature abounds with synonyms alluding to the properties of the optical brighteners: optical whiteners, fluorescent white dyes, organic fluorescent dyes, fluorescent whitening agents, fluorescent brighteners, and optical bleaching agents. Optical brighteners, however, are in no way comparable with bleaching agents; their only common property is the improvement of the whiteness of the substrate; even in this they differ in the means by which the desired effect is attained.

In all other properties the optical brighteners are closely related to dyes. They are dyes, in fact, in the sense that they change the visual appearance of the substrate to which they adhere, although they differ from dyes in the way that the desired effect is produced. A dye molecule absorbs visible light and reflects the unabsorbed portion. A fluorescent molecule absorbs invisible ultraviolet light and emits visible blue fluorescent light. It is this property that lends special status to the optical brighteners.

A variety of theories have been developed to explain dye-fiber interaction. These same theories serve to explain brightener-fiber interaction. The main theories pertaining to brightening cellulose are the theories of direct dye mechanisms:

(1). Hydrogen Bonding. The brightener molecule must be capable of forming hydrogen bonds. It should be linear, should have aromatic nuclei capable of coplanar configuration, and should contain conjugated double bonds.

(2). Van der Waal's Forces. The brightener molecule should be planar to allow the closest possible contact with the fiber. The attraction is by interaction of dipoles, between nonionic portions of the molecules. The attractive forces depend on the size and the mobility of the electron clouds. Substantivity increases with the number of conjugated double bonds.

(3). Aggregation Theory. The brightener molecule must be planar to penetrate the cellulose and enhance aggregation. The molecules pass singly into the fiber and then aggregate after losing their water of hydration. Van der Waal's forces between the dye molecules increase in strength with increasing numbers of double bonds (Stensby, 1967).

The main theories pertaining to brightening synthetic fibers, such as nylon, polyester, and acetate, are the theories of dispersed dye mechanisms: (1). The solid brightener dissolves into the solid fiber, or:

(2). The brightener molecules penetrate into "canals" between the fiber molecules, or:

(3). The water-insoluble brighteners may be soluble to a small extent. The small amount of dissolved brightener, then, would be adsorbed by the fiber, permitting more brightener to dissolve until equilibrium is reached (Stensby, 1968).

Further discussion on brightener-fiber interaction is given in Section VII, CHEMICAL REACTIVITY.

Raw textiles, papers, and plastics have a yellow tint attributable not only to the wavelength of light which they naturally absorb, but also to the colored impurities associated with the raw goods. It is well known that materials with a yellow cast can be made to look whiter by adding a blue

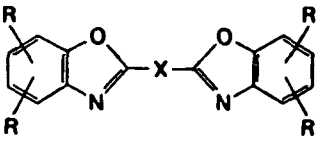
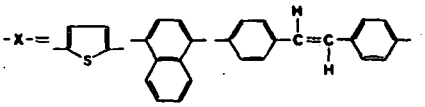
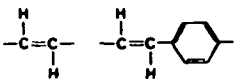
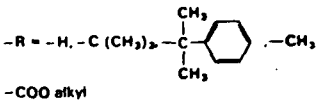
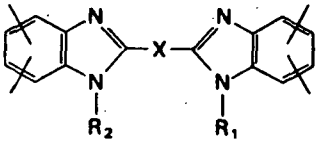
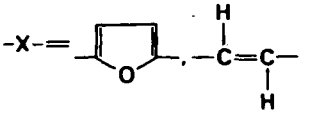
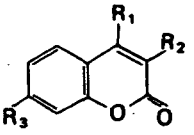
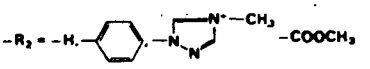
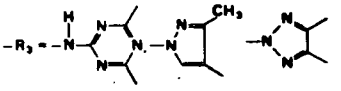
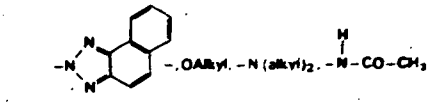
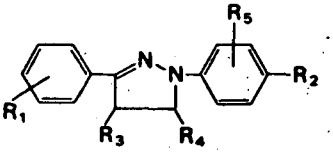
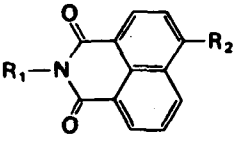
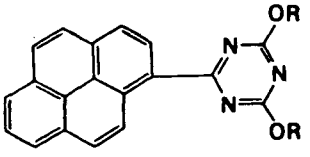
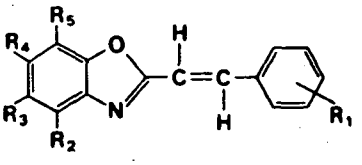
tint, as evidenced by the success of the laundering "bluing agents" which fluorished until recently. Optical brighteners correct any off-white appearance by reason of the blue-to-violet fluorescence which they exhibit under ultraviolet light as it is present in ordinary daylight.

To qualify as an additive in laundry products, a brightener must be stable to heat, water, and bleaching agents (Figs. 1, 2, and 3).

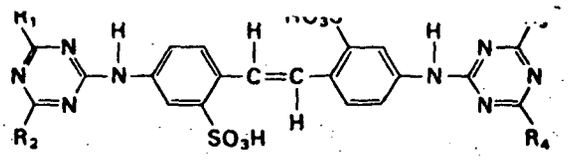
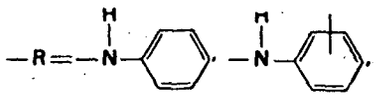
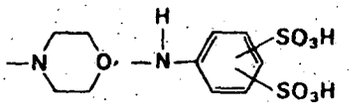
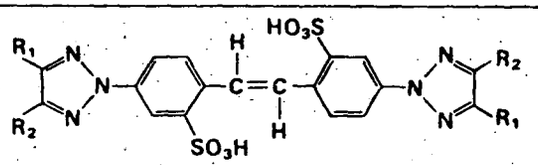
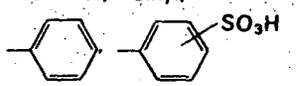
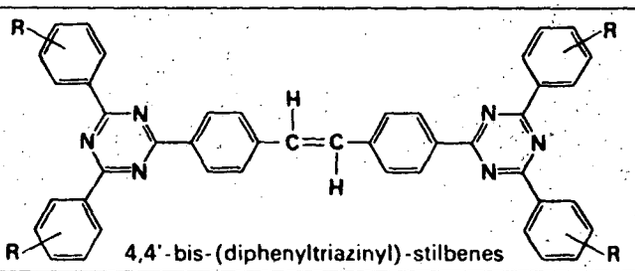
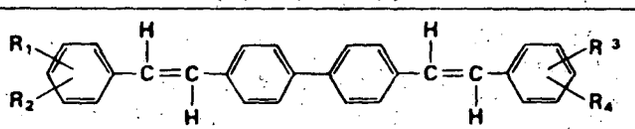
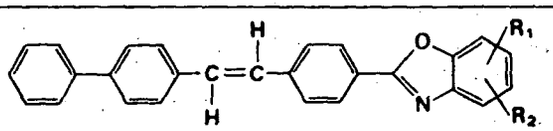
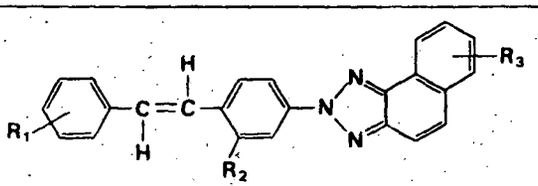
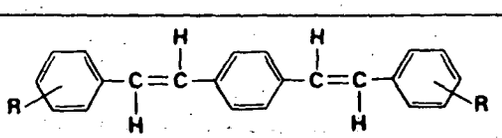
For use in the textile industry, a brightener must be light-fast and possess certain properties of fiber affinity (Figs. 4, 5, and 6).

In the plastics industry, the main areas of brightener application today are in PVC films, boards, injection mouldings, and plastisols; polystyrene boards and injection mouldings; polypropylene films and injection mouldings; polyethylene paper coatings, polyurethane coatings, thermosetting pressings and resins (Fig. 7).

Following are the basic chemical structures of some optical brighteners with the most important fields of application of their derivatives, as given in Review 1973/1, by Ciba-Geigy.

Fields of application and substrates	General basic structures	Substituents
Textiles, detergents spinning solutions/ melts, plastics polyamide (T, W) polyester (T, W, S) polyvinylchloride (K) polystyrene (K) polypropylene (K) secondary acetate (T, S) triacetate (T, S)	 bis-(benzoxazol-2-yl)-derivatives	   –COO alkyl
Textiles, detergents spinning solutions/melts cotton (W) polyamide (W) polyacrylonitrile (T, S)	 bis-(benzimidazol-2-yl)-derivatives	 $-R = -H, -CH_3, -CH_2CH_2OH$
Textiles, detergents *spinning solutions/* melts, plastics polyamide (T, W) polyester (S) polyacrylonitrile (T) polyvinylchloride (K) polystyrene (K) silk (T) secondary acetate (T) triacetate (T)	 Coumarins	$-R_1 = -H, -CH_3, -CH_2COOH$   
Textiles, detergents wool (T) silk (T) triacetate (T) secondary acetate (T) polyacrylonitrile (T) polyamide (T, W)	 *pyrazolins*	$-R_1 = -H, -Cl, -N$ $-R_3, -R_4 = -H, -alkyl,$ $-R_2 = -Cl, -SO_3H, -SO_2NH_2, -H$ $-SO_2NH-, -COO$ alkyl $-SO_2CH_3,$ $-SO_2NHCH_2CH_2CH_2\overset{+}{N}(CH_3)_3$ $-R_5 = -H, -Cl$
Textiles polyester (T) polyacrylonitrile (T) secondary acetate (T) triacetate (T)	 naphthalimides	$-R_1 = -alkyl, -CH_2CH_2CH_2\overset{+}{N}(CH_3)_3$ $-R_2 = -O$ alkyl, $-SO_3H, -NHCOCH_3$
Textiles polyester (T) secondary acetate (T) triacetate (T)	 triazinyl-pyrenes	$-R = -alkyl,$
Textiles, detergents polyamide (T, W) polyester (T, W)	 2-styryl-benzoxazoles and naphthoxazoles	$-R_1 = -CN, -COO$ alkyl, $-Cl$ $-R_2 + -R_3 =$ $-R_3, -R_5 = -H, -alkyl$ $-R_4 = -H, -alkyl,$

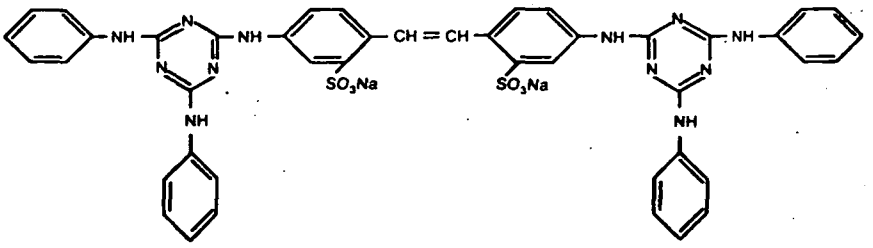
Fields of application: Textiles (T), Detergents (W), Paper (P), Spinning Solutions/melts (S), Plastics (K)

Textiles, detergents paper, spinning solutions/melts cotton (T, W) polyamide (T, W, S) cellulose (T, W, P, S)	 4,4'-bis-(triazinylamino)-stilbene-2,2'-disulfonic acids	  $-N(CH_2CH_2OH)_2$, $-N(CH_3)CH_2CH_2OH$, $-NH_2$ $-N(alkyl)_2$, $-OCH_3$, $-Cl$ $-NH-CH_2CH_2SO_3H$, $-NH\,CH_2CH_2OH$
Textiles, detergents cotton (T, W) polyamide (T, W)	 4,4'-bis-(1-triazol-2-yl)-stilbene-2,2'-disulfonic acids	$-R = -H, -alkyl,$ 
Spinning solutions/melts polyester (S)	 4,4'-bis-(diphenyltriazinyl)-stilbenes	$-R = -H, -OCH_3, -alkyl$
Textiles, detergents paper spinning solutions/ melts, plastics cotton (T, W) cellulose (T, W, P) polyamide (T, W, S) polyester (T, S) polyvinylchloride (K) polystyrene (K) polyurethane (K)	 4,4'-distyryl-biphenyls	$-R = -H, -SO_3H, -SO_2N(alkyl)_2$ $-OCH_3, -CN, -Cl, -COOCH_3$ $-CON(alkyl)_2$
Textiles, spinning solutions/melts polyester (T) polyamide (S)	 4-phenyl-4'-benzoxazolyl-stilbenes	$-R = -H, -Cl, -alkyl, -SO_2CH_3$
Textiles, detergents spinning solutions/ melts, plastics cotton (W) polyamide (W) polyacrylonitrile (S) polyester (T, W, S) polyvinylchloride (K) polystyrene (K)	 stilbenyl-naphthotriazoles	$-R_1 = -H, -Cl$ $-R_2 = -SO_3H, -SO_2N<, -SO_2OC_6H_5$ $-CN$ $-R_3 = -H, -SO_3H$
Textiles, spinning solutions/melts polyester (T) polyamide (S)	 4-styryl-stilbenes	$-R = -CN, -CON<$

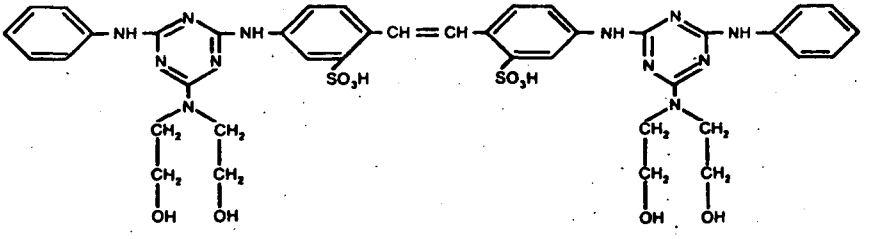
Fields of application: Textiles (T), Detergents (W), Paper (P), Spinning Solutions/melts (S), Plastics (K)

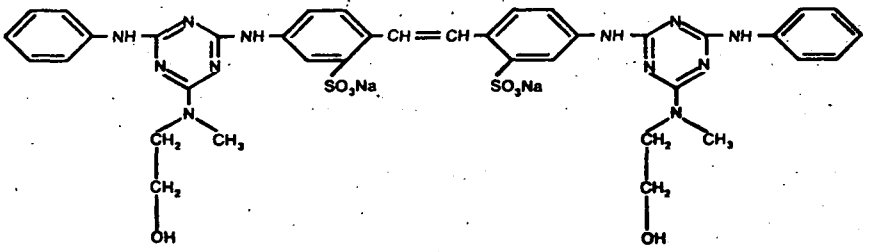
Fig. 1. OPTICAL BRIGHTENERS (FLUORESCENT WHITENING AGENTS) IN DETERGENTS

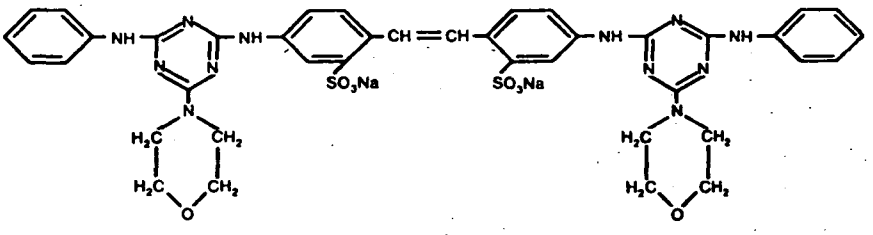
FLUORESCENT BRIGHTENER 9

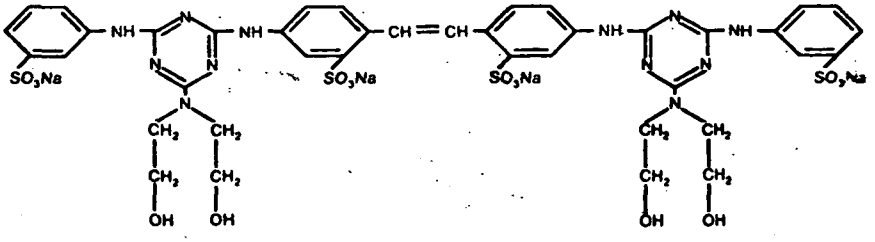


FLUORESCENT BRIGHTENER 28









SOURCE: Stensby, 1965

Fig. 2. COTTON BRIGHTENERS

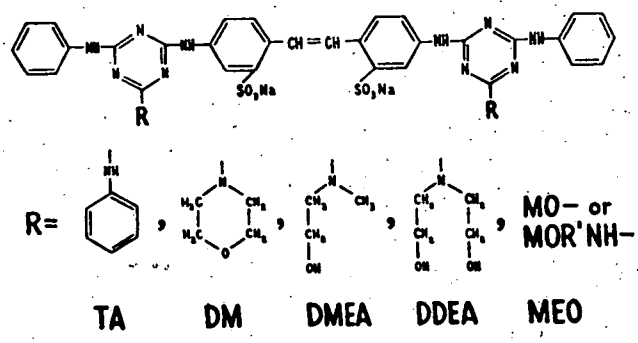
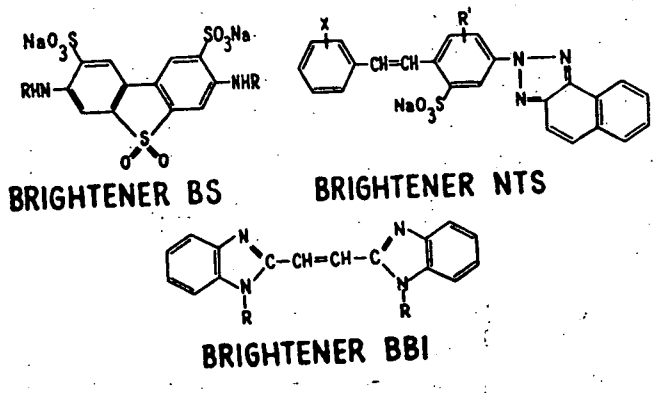
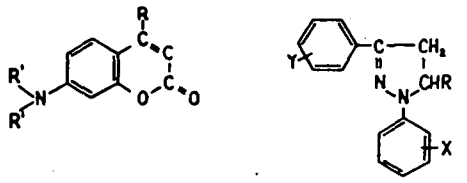


Fig. 3. BLEACH STABLE BRIGHTENERS



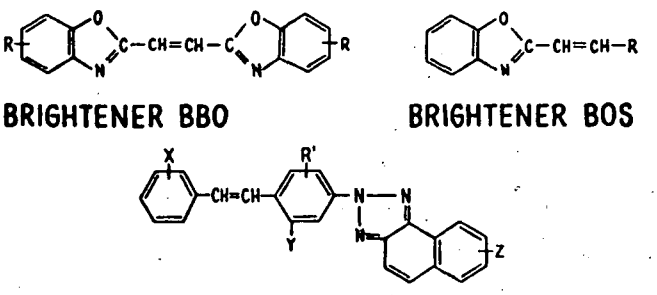
SOURCE: Stensby, 1967 a

Fig. 4. POLYAMIDE BRIGHTENERS



BRIGHTENER AC BRIGHTENER DP

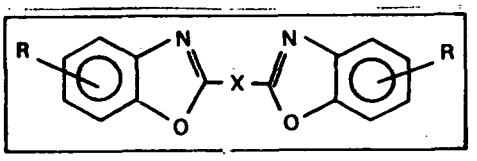
Fig. 5. POLYESTER AND POLYAMIDE BRIGHTENERS



BRIGHTENER BBO BRIGHTENER BOS

BRIGHTENER NTSA

Fig. 6.



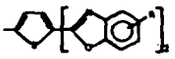
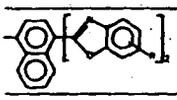
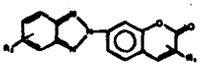
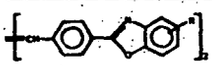
The most important properties of some polyester whiteners in relation to their chemical structure.

X	R	Thermal stability	Glycol vapour volatility	Sublimation	Shade
	$-C(CH_3)_3$	good	high	high	greenish
		good	moderate	none	greenish
naphthyl	–H	poor	high	high	bluish
naphthyl	–COOR	good	none	none	bluish-green
stilbyl	–H	poor	moderate	moderate	bluish
stilbyl	$-COOC_4H_9$	good	none	none	bluish

SOURCES: Figs. 4 and 5 - Stensby, 1967a

Fig. 6 - Review, 1973/1

Fig. 7. PROPERTIES OF VARIOUS OPTICAL BRIGHTENERS FOR USE IN PLASTICS

Structure	Fields of application	Migration stability	Light fastness	White build-up
	PVC, PS, PP, PE	very good	good	good
	PVC, PS, PP, PE	very good	good	very good
	PVC, PS, PS	good	moder-are	very good
	PVC, PS, PP, PE	moder-ate	good	moder-ate

SOURCE: Review, 1973/1

The optical brighteners are very versatile chemical compounds; most of them have more than one major application, as is shown in the tables and figures in the appendix.

There is a lack of sufficient data in the literature to establish which of the brighteners are most commonly used (the U. S. Tariff Commission does not publish individual production figures for the brighteners). Figures 1 through 7 are indicative of the major volume compounds; however, these are all based on data from Ciba-Geigy Corp. The amount of information which is published on an individual brightener (compiled in the tables given in the appendix) may be indicative of its competitive status.

According to Chemical Economics Handbook, the following figures are based on the percent of sales value by application:

	Detergents	Paper	Textiles	Fibers/Plastics
1965	63.6%	13.0%	18.3%	5.1%
1966	67.6	9.8	16.0	6.6
1967	73.3	7.7	13.0	6.0
1968	73.0	7.8	13.1	6.1
1969	72.6	8.2	12.8	6.4

These figures indicate that, in 1969, approximately 29,000,000 pounds of the brighteners produced in the United States went into detergents; 3,000,000 pounds went into paper; 4,000,000 pounds went into textiles; and 2,000,000 pounds went into synthetic fibers and plastics.

Sandoz, Inc. (Technical Bulletin I-C-2009 No. 5) recommends its Aclarat 8678 as a shampoo additive--0.01% to brighten hair and 0.05% to whiten off-white hair. This is the only direct reference to cosmetic application found in the literature. Since no C. I. Fluorescent Brightener num-

ber was found for this product, its properties are listed under the trade name at the end of the appendix.

III. PRODUCTION AND IMPORTATION

While dye production gained by 8.0% in 1972 over 1971, the production of optical brighteners fell by 8.4%. Of the total 1972 production of all compounds classified as dyes, the optical brighteners accounted for 10.4%.

The United States' manufacturers of brighteners as reported to the U. S. Tariff Commission in 1972, are: American Cyanamid Co.; Ciba- Geigy Corp.; Cincinnati Malacron Chemicals, Inc.; E. I. duPont de Nemours and Co., Inc.; GAF Corp. (Chemical Div.); Pfister Chemical Works; Sandoz, Inc. (Sandoz Color and Chemicals Div.); Hilton-Davis Division of Sterling Drug Co., Inc.; and Verona Corp.

Production figures are as follows, in pounds, as published by the U. S. Tariff Commission:

YEAR	SPECIFIC FLUORESCENT BRIGHTENERS		ALL OTHERS	TOTAL
1958				5,900,000
1959				7,000,000
1960	F. B. 68	63,000	7,429,000	7,492,000
1961	F. B. 68	72,000	9,684,000	9,756,000
1962	F. B. 68	100,000	11,746,000	11,846,000
1963	Fluorescent Brighteners are included under "ALL OTHER DYES"			
1964	F. B. 68	31,000	16,644,000	16,675,000
1965	F. B. 9	3,749,000		
	F. B. 28	1,515,000	14,156,000	19,420,000
1966	F. B. 28	1,240,000	21,972,000	23,212,000
1967	F. B. 9	318,000		
	F. B. 28	1,410	25,894,000	26,213,410
1968	F. B. 9	234,000		
	F. B. 28	1,420,000	29,643,000	30,297,000

YEAR	SPECIFIC FLUORESCENT BRIGHTENERS		ALL OTHERS	TOTAL
1969	F. B. 9	254,000		
	F. B. 28	1,676,000	37,844,000	39,774,000
1970	F. B. 28	1,593,000	29,731,000	31,324,000
1971	F. B. 28	1,574,000	28,238,000	29,812,000
1972	F. B. 28	1,604,000	25,717,000	27,321,000

Although the production of optical brighteners in the United States has declined somewhat, this cannot be taken as an indication of the prevalence of these agents without reference to import statistics. Import figures for 1972 (in pounds) are listed below. This information was taken from the U. S. Tariff Commission Reports.

OPTICAL BRIGHTENER	AMOUNT IMPORTED	OPTICAL BRIGHTENER	AMOUNT IMPORTED
F. B. 28	4,180	Ecophan	240,302
F. B. 32	5,181	Fluorescent Red 5B	110
F. B. 47	33,951	Hostalux NR	26,978
F. B. 48	5,570	Hostalux PR	1,980
F. B. 52	3,527	Leucophor PC	16,534
F. B. 55	220	Phorwite BHC	167,090
F. B. 75	1,200	Phorwite DCR	5,885
F. B. 103	220	Phorwite K	50
F. B. 112	250	Phorwite MAN	100
F. B. 119	125,040	Tinopal CH-3511	1,875
F. B. 121	79,210	Tinopal MSP	220
F. B. 134	25,792	Tinopal SFG	7,883
F. B. 140	441	Tinopal 3751	112
F. B. 148	5,250	Tuyacol 61F	11,023
F. B. 184	551	Uvitex AT	2,006
F. B. 191	77,975	Uvitex CK	22,484
F. B. 200	46,250	Uvitex EFT	496
F. B. 205	490,665	Uvitex MA	1,058
F. B. 229	77,160	Uvitex MES	2,249
F. B. 238	1,587	Uvitex NFW	220

OPTICAL BRIGHTENER	AMOUNT IMPORTED	OPTICAL BRIGHTENER	AMOUNT IMPORTED
F. B. 251	220	Uvitex 3257	332,782
F. B. 254	1,102	Uvitex 5660	1,433
F. B. 257	1,050	Other optical brighteners	3,747
F. B. 265	450		
		TOTAL	1,833,659

IV. CURRENT PRACTICE

There seem to be no particular problems in the storage, transport, or handling of the optical brighteners.

The Hilton-Davis Division of Sterling Drug Co. advises that if Hiltamine Arctic White products come into contact with the skin, it should be rinsed thoroughly with water. Precautions should be taken against entry of these products into the eyes or respiratory tract. By following these precautions, the fluorescent whitening agents should offer no health hazards in industrial handling (Hilton-Davis Technical Bulletin B-17-4/73). Data on these Hiltamines can be found in the tables in the appendix under C. I. Fluorescent Brighteners 9.1, 28, 126, 127, 128, 129, 130, 130:1, 131, and 132. Those Hiltamines with which no Fluorescent Brightener number was correlated are listed separately at the end of the tables.

American Cyanamid Co. (Technical Sales Bulletin 1056) states that all shipments of Calcofluor White RW Solution bear the following warning label:

CAUTION! May Cause Irritation.
Avoid contact with skin or eyes.
In case of contact, flush skin or eyes with plenty of water.

Further data on Calcofluor White RW can be found in the tables under C. I. Fluorescent Brightener 61.

No other directives for special handling of the optical brighteners was found in the literature.

V. ENVIRONMENTAL CONTAMINATION

The wide range of applications of the optical brighteners would make environmental contamination a distinct possibility.

Their incorporation into laundry products would suggest a transport route into surface and ground waters. During industrial production or application, brighteners may get into the effluent. Ciba-Geigy reports (Review, 1973/1) that the amounts measured in domestic effluent in densely populated areas vary between about 0.01 and 0.1 ppm (Stensby, 1968, states that the total concentration of birghtener in the liquor of the modern American home laundry would be only 3-10 mg/liter). Efficient purification plants retain more than 90% of the brighteners from industrial effluents. In very badly polluted rivers with few adjacent purification plants, doses can be of the order of 0.000001 grams per liter, while no demonstrable amounts can be found in rivers with sufficient purification plants.

Skin contact is inevitable, largely from wearing textiles that have been treated with these agents. According to Ciba-Geigy Corp. (Review, 1973/1), the high affinity for natural fibers and firm fixation in synthetic fibers do not permit the transfer of measurable amounts of FWA to the skin. The same holds true for plastics and paper which contain amounts of brightener similar to the amounts contained in textiles (0.05% and 0.15% of optical brightener).

Transference into food from brightener-treated containers and wrapping paper may lead to unintended ingestion. Low levels of brighteners persisting

in potable water would be another source of unintended ingestion. If some amount of brightener were ingested from these sources, the amount would be 10,000 times smaller than the amounts tolerated in long-term animal experiments without toxic effects (Ciba-Geigy, Review, 1973/1).

VI. MONITORING AND ANALYSIS

A comprehensive presentation of the analysis of optical brighteners is given by Kiger and Bon (1960). The following brighteners were studied in this work:

TRADE NAME	FLUORESCENT BRIGHTENER	TRADENAME	FLUORESCENT BRIGHTENER
Tinopal AN	55	Celumyl R	---
Tinopal 2B	24	Celumyl S	17
Tinopal BV	1	Blankophor BA	113
Tinopal 4BM	28	Blankophor BBV	114
Tinopal GS	47	Leucophor B	32
Tinopal RBN	59	Leucophor 2B	---
*Tinopal SP	18	Leucophor BS	49
*Uvitex BT	19	Leucophor R	30
Uvitex GS	42	Leucophor RG	14
Uvitex RBS	---	Fluotex CBL	21
Uvitex RS	41	Fluotex CDC	---
Uvitex RT	37	Blankit 1A	---
Uvitex VR	142	*Ultraphor GPB	114
Celumyl BW	---	Pontamine White G	---

*These brighteners are not being currently manufactured.

The most suitable solvent for these brighteners was a mixture of 95 parts of pyridine to 5 parts of ammonium hydroxide. To extract the brighteners from cotton fabric for assay, 2 gm of fabric (approximately 10 x 10 cm) was placed in a 100 ml flask with 30 ml of a 5% solution of ammonium

hydroxide in pyridine and was shaken for two hours. The extract was concentrated to 3-5 ml on a water bath.

Detection methods are summarized as follows:

Circular Paper Chromatography: Results were obtained within two hours, but were not satisfactory enough to merit further study. No migration took place with dichloroethane, cyclohexanone, ethyl acetylacetate or methylcyclohexanone. Spots were displayed with butyl acetate and isobutanol. Migration was quite variable with neutral or acidic acetone, with neutral or acidic acetone, methanol, with propanol, and with dimethylformamide.

Column Chromatography: A 5 mm alumina column was used and development took place in approximately two hours per ml of solution. The differences in the fluorescence of the chromatograms were too weak to allow definite identification of the brighteners.

Ascending Paper Chromatography: The brighteners in a pyridine-ammonia solution were run in a mixture of butanol, acetic acid, and water in the ratio of 80:20:100. It was possible to classify a certain number of groups from the chromatograms, but individual brighteners within the groups could not be identified because of identical migrations. The author gives a tabulation of the R_f values obtained in this study.

Electrophoresis: Microelectrophoresis under high voltage was applied for five hours. An exact pH of 8.6 was attained by using the following mixture: 29.428 g of sodium veronal, 19.428 g of sodium acetate, 180 ml of 0.1 N hydrochloric acid, and 3 L of distilled water. The author gives a tabulation of the R_f values obtained in this study, both of the pure products and of the products extracted from fabric.

Spot Fluorescence on Textiles: One drop of a mixture of 10% sulfuric

acid, 4% sodium hydroxide, sodium hypochlorite, and hydrogen peroxide was applied to samples of fabric and of paper which had been treated with brighteners. The results obtained from the fabric samples differed from those of the paper samples. The brighteners could be differentiated by groups. All results are tabulated by the author.

O'Hare (1966) gives a simple test method which is accurate to ±5%, in which anionic brighteners are titrated with cationic Methylene Blue G to give a water-insoluble complex which does not fluoresce. The end-point is observed under ultraviolet light.

Spectrophotometric analysis of optical brighteners is described by Weeks, Harris, and Lewis (1959).

A 0.2500 g sample of brightener was transferred to a foil-wrapped Erlenmeyer flask and the weighing pan was washed with 200 ml of absolute methanol. One ml of 40% aqueous sodium hydroxide was added to aid dissolution. The mixture was heated at 55-60°C for several minutes, after which it was transferred to a 1000 ml flask. The Erlenmeyer flask was rinsed with 200 ml of water and then by 200 ml of methanol. The flask contents were diluted to 1000 ml with 67% aqueous methanol. The resulting solution contained 0.0250% brightener and was used as the stock solution.

It is important that non-ionic, actinic glassware be used throughout, and that the solution be absolutely protected from any ultraviolet radiation.

Test solutions were prepared by diluting 5, 10, 15, 20, and 25 ml aliquots of the stock solution with 67% aqueous methanol to the mark in 250 ml actinic volumetric flasks to yield brightener concentrations of 0.0005%, 0.0010%, 0.0015%, 0.0020%, and 0.0025%.

A Cary spectrophotometer was calibrated to zero absorbancy over the range of 300 mu to 400 mu with 67% aqueous methanol in both the blank cells and test cells. It was operated at 0.6 mu per second. The ultraviolet absorption spectra were determined for the brightener test solutions at 0.0010% concentration.

Once the absorbancy characteristics of a brightener were known, the other solution concentrations were analyzed at the wavelength providing maximum absorbency. After a concentration vs. maximum absorbancy curve is made for a standard of reference brightener, it is then possible to analyze other samples of the same type for relative purity.

Some idea of the brightener present in an unknown detergent composition may be gained by: 1) Determination of stability of the brightener to hypochlorite bleach; 2) Washing a spectrum of fibers to determine affinity characteristics of a brightener; and 3) Fluorescence spectrum of the washed fabric.

Functional properties of brighteners are suggested as a means to characterize them. It should be possible to identify unknown brighteners by comparing their functional properties with those for knowns.

Colorimetry in the visible range is described by Taylor (1955), using a Spekker fluorimeter (Hilger and Watts). This work is limited to comparative strength determination of chemically identical samples. The following brighteners were studied:

TRADE NAMES	FLUORESCENT BRIGHTENER	TRADE NAMES	FLUORESCENT BRIGHTENER
Uvitex RS	41	Uvitex WGS	61
Uvitex GS	42	Uvitex RSW	--
Uvitex RBS	--	*Uvitex NA	58
Uvites RT	37	Uvitex WS	--
*Uvitex W	57		

*These brighteners are not being currently manufactured.

Transmission vs. concentration values and reflectance vs. concentration values were obtained and used as standard curves. Ethyl alcohol or Cellusolve were the preferred solvents.

Taylor states that no attempt should be made to obtain even a rough comparison of the fluorescence of brightening agents which are not chemically similar, in water or in any other solvent. Also, the fluorescence of a product in solution gives no reliable indication of its fluorescence when adsorbed on the substrate for which it is intended.

A major difficulty encountered in the fluorimetry of brighteners in solution is the appreciably differing absorptions for ultraviolet radiation between the cis and trans isomers of the stilbene series. In certain cases, no steady state of equilibrium was attained and the test had to be abandoned.

VII. CHEMICAL REACTIVITY

It is physical fluorescence and not chemical reactivity that is the primary characteristic of an optical brightener. In fact, a highly reactive molecule would be disqualified as a brightener, as it must remain stable to the rigorous conditions to which it is submitted during application and use.

A brightener must have certain structural features: a series of conjugated double bonds to give it fluorescence; one or more solubilizing groups (such as sulfonic acid groups); NHCO groups, or sufficiently high molecular weight, to have affinity for the fiber (Adams, 1954).

Brightener-fiber interactions are discussed briefly in Section I, PROPERTIES AND USES, and are discussed here in greater detail.

Cellulosic fibers absorb water and swell when in contact with water.

Brightener molecules are then admitted to the fibers and pass through water-filled channels by diffusion. These brightener molecules may interact with the fiber by either of two bonding mechanisms:

(a) A brightener molecule which is capable of forming a hydrogen bond with the substrate will do so. A hydrogen bond is formed when a hydrogen atom on one molecule forms an addition bond to an electronegative atom on another molecule, thereby creating an attractive force which holds these interacting molecules together. The energies of hydrogen bonds are 5 kcal/mole, well below normal bond energies, and too weak to be considered as true chemical bonds.

(b) Van der Waal's forces result in a weak attractive force between the brightener molecules and the fibrous substrate, by dipole moment interaction. Although these forces are electrical in nature, their bonding energies are far less than the energies of hydrogen bonds, and so are too weak to be considered as true chemical bonds.

Van der Waal's forces are the principal forces which bind dispersed brightener molecules to hydrophobic synthetic fibers, such as nylon, polyester, and acetate. The dispersed dyestuff particles are relatively small in size, have low solubility, and are neutral in character. These particles may either dissolve into the solid fiber, penetrate the fiber between the fiber molecules, or simply deposit onto the fiber. Van der Waal's forces then establish the attraction between the fiber and the brightener molecules.

Individual optical brighteners exhibit different fastness properties and different stabilities, depending on individual chemical constitutions and the reactive strength of other chemicals present during application

and use. The fastness and stability characteristics of the individual brighteners are given in the tables in the appendix.

For application in the textile industry, the brighteners, after incorporation into the fibers, must have fastness to light; must withstand frequent washings in detergents or dry-cleaning; must be inert to atmospheric gases; and must remain fast to ironing, perspiration, deodorants, and friction in use (Stensby, 1967).

To be suitable as a detergent additive, a brightener must be stable to severe processing conditions in a strongly alkali medium at high temperatures. It must remain stable during storage of the product, remain stable in solution, and be inert to bleach and to other detergent additives (Stensby, 1968; Siegrist, 1955).

The optical brighteners selected for use in the paper industry must be compatible with the chemicals used in paper making, including chlorite bleach. They must have good storage stability and affinity for pulps and fillers, and they should have good tolerance to sizes, bonding agents, wet strength resins, and retention agents. They must be fast to alum, alkalies, and acids, and must be insensitive to hard water (Review, 1973/1).

Whiteners for incorporation into polymers have great demands made on their thermal and chemical behavior during addition at the polyester or polymerization stage with polyamide. The whiteners must be so stable thermally that they withstand the high temperatures necessary for polymerization or polycondensation, without any noticeable degradation. They must not be volatile, nor must they sublime from the melt in a vacuum (Review, 1973/1).

Those brighteners which are incorporated into pigmented coatings must have outdoor durability and thermal stability.

VIII. BIOLOGY

A. ABSORPTION

Experiments with three strains of bacteria, three strains of fungi, and three strains of yeast show that some optical brighteners are absorbed by microorganisms and transported to new cells. Specific names for the brighteners tested are not given, except for 4,4'-bis[4-anilino-6-bis(2-hydroxyethyl)amino-s-triazin-2-ylamino]-2,2'-stilbenedisulfonic acid (Darken, 1962). Complete data on this brightener is compiled in the tables in the appendix, under C. I. Fluorescent Brightener 28.

In those investigations during which brighteners were topically applied to skin and mucous membrane, no toxic effects were noted. Snyder (1963) applied stilbene disulfonates and other common brighteners used in detergents to the skin of mice, rats, guinea pigs, and rabbits over a two-year period without any development of toxic symptoms from absorption. Alexander (1964) recommends further study on the possibility of incorporating brighteners into cosmetics, since his review of the literature indicated no toxicity from topical application. The only direct reference to brighteners which are actually recommended for cosmetic use is published in Sandoz, Inc. Technical Bulletin I-C-2009 No. 5. Aclarat 8678 is recommended for use as a shampoo additive. Other information on this brightener is listed under the trade name at the end of the tables in the appendix.

The stilbene character of most optical brighteners might have an

estrogenic effect after accumulation and resorption through the skin. Brighteners were injected subcutaneously in doses of 100-600 mg/kg into rats, and for three weeks brighteners were applied to the skin. The conclusion was drawn that the stilbenedisulfonic brighteners do not resorb, as evidenced by a lack of estrogenic effect. In this same experiment a 1% solution of Blankophor brighteners was applied to the skin of post-menopausal women for a period of three weeks. No stilbene groups were found in the urine, and Papanicolaou smears indicated no estrogenic activity (Schneider, 1955). Schneider does not indicate which specific brighteners were used in this study.

B. EXCRETION/ELIMINATION

Diaminostilbenedisulfonic acid derivatives of the Blankophor series were administered intraperitoneally to cats in doses of 50 mg/kg. The largest amount of brightener was initially excreted in the urine, with subsequent smaller amounts being detected over a period of time until the total amount of brightener had been eliminated. After an oral administration of the same dosage, brightener could be detected for 2 days in the urine of the cats by qualitative fluorescence, but could not be determined quantitatively (Gloxhuber, 1962).

A common brightener, 4-methyl-7-diethylaminocoumarin, was given orally and intravenously to rabbits, after which the route of elimination was determined to be in the bile and in the urine. (Gouaze, 1963). Other data on this brightener are listed at the end of the tables in the appendix, under the trade name Advabrite MDAC.

C. TRANSPORT AND DISTRIBUTION

The tissue affinity of one hundred forty-eight optical brighteners

for the tissues of lower animals was studied by Gouaze (1963). Soluble compounds were administered both intravenously and orally while insoluble compounds were administered only orally to mice, rats, rabbits, and dogs.

The di-sodium salt of (2-oxo-4-imidazoline-4,5-diyl)dibenzenesulfonic acid, a non-toxic, soluble compound, had no affinity for the spleen or nervous system. It gave a general fluorescence to the skin, mucosa, intestinal tract and muscles.

4,4'-Bis[4-anilino-6-(bis(2-hydroxyethyl)amino-s-triazin-2-yl)amino]-2,2'-stilbenedisulfonic acid, a non-toxic, soluble compound, gave general fluorescence to the skin, mucosa, intestinal tract and muscles. It showed affinity for the spleen, fatty tissue, nervous system, pancreas, and glandular system. Complete data on this compound are listed in the tables in the appendix under C. I. Fluorescent Brightener 28.

7-(Diethylamino)-4-methylcoumarin, a soluble compound having a slight toxicity, had an affinity for the nervous system. Other data on this compound are listed in the tables at the end of the appendix, under Advabrite MDAC.

1-[p-[(2-Hydroxypropyl)sulfonyl]phenyl]-3-phenyl-2-pyrazoline also had an affinity for the nervous system.

Derivatives of diaminostilbenetriazine had an affinity for the spleen and for the nervous system.

Derivatives of bis-benzoxazole had an affinity for the pancreas, salivary glands, thyroid, adrenals, pituitary, ovaries, and testes.

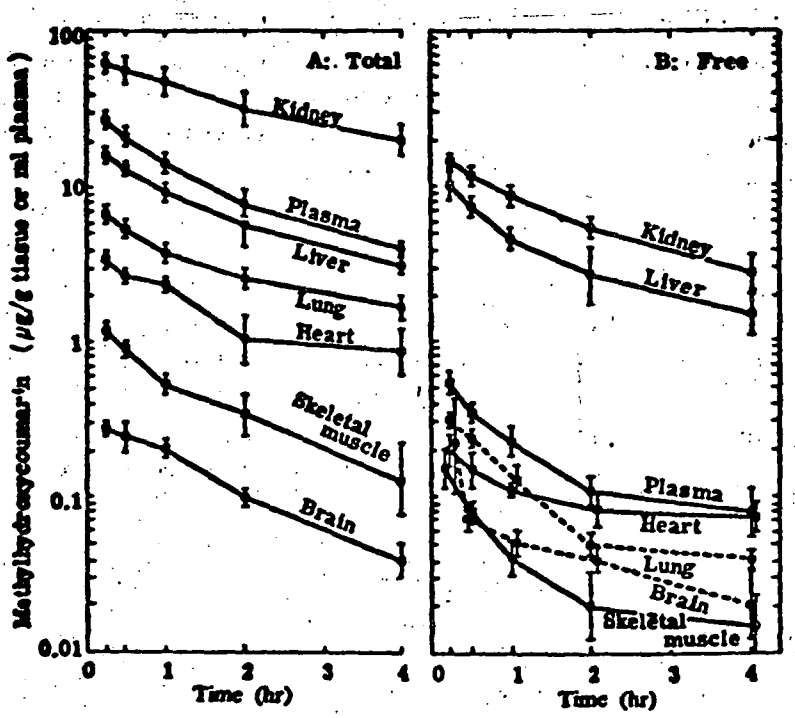
Gouaze (1963) administered 7-(diethylamino)-4-methylcoumarin and several pyrazole derivatives, such as 1-[p-[(2-hydroxypropyl)sulfonyl[phenyl]-3-phenyl-2-pyrazoline, to rabbits, both orally and intravenously.

He found that these compounds were taken up by the brain and nervous system.

The distribution of 7-hydroxy-4-methylcoumarin was investigated in the rats. Male Sprague-Dawley JCL strain rats, weighing 200 to 250 g, were given 50 mg of methylhydroxycoumarin (1% suspension in 0.5% carboxymethylcellulose solution) per kg of body weight, by means of a stomach tube.

The cumulative amounts of free methylhydroxycoumarin recovered from urine after 24, 48, and 72 hours were 2.96%, 3.04%, and 3.12%, respectively, of the administered dose.

Following are the tissue and plasma concentrations of total (conjugated + free) and free methylhydroxycoumarin in the rat. A vertical line indicates a standard error.



Source: Tomura, 1971

The distribution of free methylhydroxycoumarin was markedly different from that of total methylhydroxycoumarin. The level of the free form in

the brain was not statistically different from those in cardiac muscle, lung, and skeletal muscle and was 20% to 30% of that in the plasma. The free form of the drug was predominant in the brain.

D. METABOLISM AND METABOLIC EFFECTS

The di-sodium salt of diaminostilbenedisulfonic acid inhibited the respiration of rabbit liver homogenate 41.0% at 1.5×10^{-6} M and 62.2% at 1.5×10^{-5} M. Subcutaneous injection of 200 mg/kg of the di-sodium salt of 4,4'-bis(1,3,5-triazin-6-ylamino)stilbene-2,2'-disulfonic acid into rabbits increased urinary excretion of lactic and pyruvic acids but did not affect excretion of citric acid (Ukita, 1960).

The major metabolic pathway for 7-hydroxy-4-methylcoumarin is as a sulfate conjugation (Tomura, 1971). This was demonstrated by sulfatase hydrolysis of the conjugated form in plasma, diluted urine, or in 10% water homogenate of tissue after a 50 mg oral administration of methylhydroxycoumarin to rats. The free compound was determined in the urine at levels of 2.96%, 3.04%, and 3.12% of the administered dose. After the sulfatase hydrolysis these values increased to 85.7%, 87.0%, and 94.6%.

The free form of the compound was predominant in the brain, demonstrating that free methylhydroxycoumarin, which is low in liposolubility, penetrates through the blood brain barrier very easily. Its lipid insoluble metabolite, the conjugated form, does not gain access to the brain.

IX. ENVIRONMENTAL TRANSPORT AND FATE

A. PERSISTENCE AND/OR DEGRADATION

From the information gathered on the chemical properties of molecules which qualify them for use as optical brighteners, it would seem that

they would persist in the environment. Their inertness to the various other chemicals with which they come into contact during application, and their stability under the severe conditions to which they are subjected during processing and use, would support this assumption.

No information on the decomposition products of the brighteners is published. Individual stabilities to various agents are listed under the individual compounds in the appendix.

B. ENVIRONMENTAL TRANSPORT

The brighteners are carried both on and in the tremendous variety of substrates to which they are applied. However, water-transport would be the main area of concern related to environmental significance.

C. BIOACCUMULATION

No information was uncovered concerning the bioaccumulation of the optical brighteners. It would seem, however, that fat-soluble molecules might accumulate in animal tissues.

X. TOXICITY

A. HUMAN TOXICITY

Contact or accidental ingestion would be the major pathways by which the optical brighteners could demonstrate toxicity toward humans. Textile materials which are worn contain between 0.05%-0.15% of optical brightening agents. Their fastness on the fiber substrate would argue against transference to the skin. The amount of brightener that might be accidentally ingested, as from an agent transferring into food from a brightener-treated container would be negligible. The amount of brightener persisting in potable water, if ingested, would be approximately 1 microgram per liter; this amount is 10,000 times smaller than the amounts tolerated in

long-term animal experiments without the slightest effect (Review, 1973/1).

Ten derivatives of 4,4'-diamino-2,2'-stilbenedisulfonic acid were used in patch tests (1%) on eight human subjects. Seven subjects revealed no reactions, but a transient hyperemia occurred in one case. Intracutaneous injection of the brighteners in a 1% aqueous solution caused necrosis and infiltration. These compounds showed no photosensitizing effect (Gloxhuber, Hecht, and Kimmerle, 1962). In similar patch tests, Schneider (1955) noted no reaction unless ultraviolet light or abrasive action was employed. Alexander (1964) conducted patch tests on 2000 subjects, using dilutions of optical brighteners from 10 mg/L to 100 mg/L. Readings were taken after 24 and 48 hours, and repeat applications were made at two-month intervals; 53 of the 2000 subjects showed weakly positive sensitization reactions after 24 hrs; 87 of the 2000 subjects displayed erythema. Glashoff (1963) applied washing powders and soaps containing optical brighteners to human skin in a 5% solution. The solution was reapplied for 6 days. No sensitization was noted. In further investigations, 87 dermatology patients were tested, with similar results.

Keplinger, Fencher, Lyman, and Calandra (1974) tested the following optical brighteners for sensitization induction in human subjects:

(I) 4-(2H-naphtho[1,2-d]triazol-2-yl)-2-stilbenesulfonic acid, sodium salt

Tinopal RBS (Ciba-Geigy Corp.)

Fluorescent Brightener 46

(II) 4,4'-Bis[[[4-anilino-6-(2-hydroxyethyl)(methyl)amino]-s-triazin-2-yl]amino]-2,2'-stilbenedisulfonic acid, disodium salt

Tinopal AMS (Ciba-Geigy Corp.)

(III) 4,4'-Bis[[[4-anilino-6-(2-hydroxyethyl)(methyl)amino]-s-triazin-2-yl]amino]-2,2'-stilbenedisulfonic acid, disodium salt
Tinopal 5BM (Ciba-Geigy Corp.)

(IV) 2,2'-(4,4'-biphenylylenedivinylene)dibenzenesulfonic acid, disodium salt

Patches containing these brightening agents were applied to human skin, three times a week, with a total of ten patches being applied to the same site. After a rest period of 10-14 days, a challenge patch was applied. Examinations 24 hours and 48 hours later revealed neither irritation nor sensitization in 50 human subjects.

According to American Cyanamid Co. (Technical Sales Bulletin 1056), Calcofluor White RW (C. I. Fluorescent Brightener 61) shipments bear a warning label which states that this compound is a skin and eye irritant.

B. TOXICITY TO NON-HUMAN MAMMALS

1. Acute, Subacute, and Chronic Toxicity

Gloxhuber, Hecht, and Kimmerle (1962) studied the following brighteners in relation to animal toxicity:

TRADE NAME	FLUORESCENT BRIGHTENER
Blankophor R	30
Blankophor G	40 (not presently manufactured)
Blankophor B	--
Blankophor BE	115
Blankophor BH	--
Blankophor BBH	121
Blankophor BGH	--
Blankophor BUP	--
Blankophor HZN	--
Blankophor PM	--
Blankophor H type B	--

ACUTE TOXICITY, SINGLE ORAL ADMINISTRATION, LD_{50} (g/kg)

Blankophor	Rats	Guinea Pigs
B	> 5.0	>2.0
BH	3.0	0.25
BBH	> 2.0	>1.0
BGH	> 2.0	>1.0
G	> 5.0	2.0
H type B	> 5.0	1.0
R	> 5.0	0.5
BUP	>10.0	>2.5
HZN	> 2.5	>2.5
PM	>10.0	---

Doses higher than 1.0 g/kg were not administered to rabbits nor cats. At this level, these animals survived with no toxic reactions.

ACUTE TOXICITY, SINGLE PARENTERAL ADMINISTRATION, LD_{50} (g/kg)

Blankophor	Mice (iv)	Rats (ip)	Mice (sc)
B	0.1	1.0	0.5
BH	0.3	0.5	1.0
BBH	---	0.35	1.5
BGH	---	0.75	1.0
G	---	0.5	---
H type B	0.35	0.35	1.0
R	0.35	0.35	1.0
BUP	0.9	1.75	1.5
HZN	---	0.4	---
PM	0.8	1.75	---

After intraperitoneal injection of 50 mg/kg of Blankophor B to cats, the brightener was excreted in the urine over a two-day period without any toxic effect.

REPEATED ORAL ADMINISTRATION

Rats, rabbits, and cats were given oral doses of Blankophors B, BH, BBH, BGH, G, H type B, R, BUP and HZN, over a 2-4 week period, at levels of 0.1-0.5 g/kg. No recognizable toxic effects were noted.

CHRONIC FEEDING STUDY

Male rats, weighing 50 g, were given optical brighteners in their drinking water. Results are given as follows:

Blankophor	Concentration %	Test Time (days)	Total Amount Administered
R	0.2	498	20.3
BH	0.5	464	35.5
BBH	0.2	362	18.0
BGH	0.2	362	12.0

One animal from the R group expired after 7 days; one animal from the BGH group expired after 269 days; and one animal from the BBH group expired after 330 days. The weight of the survivors did not differ from that of the controls. During the time period of the experiment, the survivors showed no toxic symptoms. The average life-span of the survivors was 700 days, calculated from the beginning of the test period.

EFFECT ON MUCOUS MEMBRANES

Aqueous solutions of the Blankophor brighteners produced no particular irritation of animal mucous membranes. A 1% solution of Blankophor BUP produced a transient hyperemia of the rabbit conjunctival sac. Blankophor BBH and BE showed no such effect.

INTRACUTANEOUS ADMINISTRATION

The intracutaneous administration of 1 ml of a 1% solution of the Blankophor brighteners to rabbits resulted in infiltration and localized

necrosis. Blankophors BUP and PM were exceptions; they produced no adverse effects.

CHRONIC PARENTERAL ADMINISTRATION

Male rats were given parenteral injections of 0.5 ml of 1% solutions of the Blankophor brighteners twice weekly for one year. Any ulcerations which formed healed normally after interruption of the treatment.

PHOTOSENSITIZATION

Control mice were given subcutaneous injections of Hypericin in doses of 25 mg/kg. A rapid onset of toxic symptoms appeared when these animals were placed in sunlight, and 4 of the 5 animals treated expired within 12 hours. Similarly treated control animals survived in the dark.

The test mice were given doses of 0.25 g/kg of Blankophors R and BH, subcutaneously. No difference was found between those mice which were kept in sunlight and those which were kept in darkness.

ACUTE DUST INHALATION

Keplinger, Fancher, Lyman, and Calandra (1973) exposed rats for four hours to the highest dust concentration achievable (2900-5500 mg/m^3) of the following optical brighteners:

(I) 4-(2H-naphtho[1,2-d]triazol-2-yl)-2-stilbenesulfonic acid, sodium salt

Tinopal RBS (Ciba-Geigy Corp.)

Fluorescent Brightener 46

(II) 4,4'-Bis[(4-anilino-6-morpholino-s-triazin-2-yl)amino]-2,2'-stilbenedisulfonic acid, disodium salt

Tinopal AMS (Ciba-Geigy Corp.)

(III) 4,4'-Bis[[[4-anilino-6-(2-hydroxyethyl)(methyl)amino]-s-triazin-

2-yl]amino]-2,2'-stilbenedisulfonic acid, disodium salt

Tinopal 5BM (Ciba-Geigy Corp.)

(IV) 2,2'-(4,4'-biphenylybenedivinylene)dibenzenesulfonic acid, disodium salt

Compounds II and IV caused grooming, sneezing, inactivity, and weakness on inhalation by the rats, but induced no pathological changes. Lung hyperemia was found in two out of ten rats which inhaled compound I. Lung consolidation was found in four out of ten rats, and one rat expired. Compound III induced inactivity in the animals inhaling it. Slight lung hyperemia was found in three out of ten rats and lung consolidation was found in 2 out of ten rats.

Fontaine (1968) investigated the oral, intraperitoneal, and intravenous LD_{50} values of 4-methylumbelliferone (7-hydroxy-4-methylcoumarin) in male mice. These values were 7500, 325, and 250 mg/kg, respectively. In male rats, the oral and intraperitoneal LD_{50} values were 6200 and 750 mg/kg respectively. This compound caused ataxia and tranquilization in both mice and rats. The i.v. LD_{100} was 251 mg/kg (respiratory arrest) and 292 mg/kg (cessation of the QRS complex), following infusion of 5 mg/ml/min into anesthetized rats. A three month oral administration of doses of 200 or 40 mg/kg/day to young rats did not affect growth, food intake, mortality, blood picture, or organ histology. No blood, acetone, bile salts, or bile pigments appeared in the urine.

2. Sensitization

No sensitization is reported in any of the published articles studied irrespective of the type of animal studied, amount of optical brightener administered, route of administration, or duration of experiment

(Gloxhuber, Hecht, and Kimmerle, 1962; Schneider, 1955; Alexander, 1964; Glashoff, 1963; Keplinger, Fancher, Lyman, and Calandra, 1974).

3. Teratogenicity

Fontaine (1968) studied the teratological effects of 7-hydroxy-4-methylcoumarin in rats. This brightener demonstrated no teratological effects when administered orally to pregnant rats in doses of 15-1200 mg/kg/day from the 6th to 15th days of gestation; to mice at 50, 200, or 800 mg/kg/day for 15 days before mating; nor to rabbits at 50, 200, or 800 mg/kg/day from days 6 through 15 of gestation.

Keplinger, Fancher, Lyman, and Calandra (1974) studied the teratogenic activity of four optical brighteners in rabbits. The brighteners were administered at dose levels of 10 and 30 mg/kg. Results are tabulated as follows:

SUMMARY OF TERATOGENIC EFFECTS OF FOUR FLUORESCENT WHITENING AGENTS IN ALBINO RABBITS

Test material	Dose (mg/kg)	No. of pregnant females	No. of implantations	No. of resorptions	No. of normal fetuses	No. of abnormal fetuses
None	—	12	99	8 (8.1%)	91	0
	—	12	112	9 (8.0%)	99	4
Thalidomide	37.5	10	70	13 (18.6%)	54	3
	37.5	10	124	24 (19.3%)	85	15
	75	7	55	15 (27.2%)	26	14
Compound I[a]	10	14	118	10 (8.5%)	108	0
	30	13	105	10 (9.5%)	95	0
Compound II	10	17	147	16 (10.9%)	131	0
	30	16	140	19 (13.6%)	121	0
Compound III	10	16	117	20 (17.1%)	97	0
	30	11	90	24[b] (26.7%)	65	1
Compound IV	10	13	91	17 (18.7%)	74	0
	30	16	132[c]	15 (11.3%)	107	1

[a] Test material neutralized to pH 7 with hydrochloric acid.
[b] 15 were from 2 females only.
[c] 9 were aborted from 1 female.

(I) 4-(2H-naphtho[1,2-d]triazol-2-yl)-2-stilbenesulfonic acid, sodium salt

Tinopal RBS (Ciba-Geigy Corp.)

Fluorescent Brightener 46

(II) 4,4'-Bis[(4-anilino-6-morpholino-s-triazin-2-yl)amino]-2,2'-stilbenedisulfonic acid, disodium salt

Tinopal AMS (Ciba-Geigy Corp.)

(III) 4,4'-Bis[[[4-anilino-6-(2-hydroxyethyl)(methyl)amino]-s-triazin-2-yl]amino]-2,2'-stilbenedisulfonic acid, disodium salt

Tinopal 5BM (Ciba-Geigy Corp.)

(IV) 2,2'-(4,4'-biphenylybenedivinylene)dibenzenesulfonic acid, disodium salt

4. Carcinogenicity

No evidence was found in the literature to prove that the optical brighteners are carcinogenic to either humans or animals.

Bingham and Falk (1970) attempted to demonstrate synergism between the optical brighteners and ultraviolet light in malignant tumor development. The compounds tested were: (I) 3-benzyl-4-methyl-7-hydroxycoumarin; (II) 4,4'-bis(2,4-dimethoxybenzamido)-2,2'-stilbenedisulfonic acid, disodium salt; and (III) 4,4'-bis(4,6-dianilino-s-triazin-2-yl)amino-2,2'-stilbenesulfonic acid, disodium salt [Fluorescent Brightener 9].

Groups of 50 young adult C3H mice were treated with a 1% solution of optical brightener in DMSO (dimethyl sulfoxide) or with DMSO alone as a control. A dose of 50 mg of solution was applied 3 times weekly to the skin of the intrascapular region, for the lifetime of the mouse or until a tumour appeared.

Tumours did not occur in any mice receiving topical applications of the optical brightener alone, but a high incidence of tumors developed in all three test groups with the addition of ultraviolet light (254 mu). Histological examination of the tumors revealed that they were squamous cell carcinomas.

Optical brightener II appeared to be slightly more active than either I or III. Two carcinomas developed in the mice that were treated with solvent and light. No tumors developed in the group receiving applications of solvent alone.

However, this work has been called irrelevant by Berth, Fischer, and Gloxhuber (1972), since the wavelength of ultraviolet light used by Bingham and Falk (254 mu) does not occur in natural light, making the results obtained invalid in practice.

Neukomm and DeTrey (1961) studied the carcinogenic properties of the following brighteners:

(I) 4,4'-bis[[4-anilino-6-[(2-hydroxyethyl)methylamino]-s-triazin-2-yl]amino]-2,2'-stilbenedisulfonic acid, disodium salt;

(II) 4-(2H-naphtho[1,2-d]triazol-2-yl)-2-stilbenesulfonic acid, sodium salt (Fluorescent Brightener 46); and

(III) 4-(7-sulfo-2H-naphtho[1,2-d]triazol-2 yl)-2-stilbenesulfonic acid, disodium salt.

A group of 50 female mice, aged 3 to 6 months were used as controls.

A second group of 50 mice of the same sex, age, and strain were injected subcutaneously with a mixture of 0.2 ml of 8g of talc in 20 g of peanut oil. These were used as solvent controls.

A third group of 50 mice of the same sex, age, and strain were in-

jected with 0.5 mg of 3,4-benzopyrene in 0.2 ml of peanut oil. These were used as comparison controls in tumor formation.

Fifty test mice, identical in sex, age, and strain to the control mice, were injected subcutaneously with the optical brighteners at a dose level of 5 mg of brightener in 0.2 ml of a mixture of talc and peanut oil, 0.5 mg of brightener per day per animal in food.

The duration of the experiment was two years.

The lungs, heart, liver, spleen, and kidneys of each animal were examined both grossly and histologically after expiration.

No mice receiving the brightener test compounds presented tumors at the injection site, nor did the talc-oil controls. The 3,4-benzopyrene controls developed fibroblasts at the injection site.

Mammary tumors, ovarian cysts, and incidence of leukemia were not accelerated by the brighteners when compared with the controls.

Although there were no general toxic effects noted during these long-term studies, a few cases of splenic amyloidosis and liver damage might be attributable to the long-term feeding of brighteners to the affected animals (comparable doses for humans would amount to 20 mg/kg, or 1.2 g per day).

5. Mutagenicity

The mutagenic effects of some optical brighteners toward microorganisms are discussed in Section E, TOXICITY TO MICROORGANISMS.

Keplinger, Fancher, Lyman, and Calandra (1974) tested the following brighteners for mutagenic effects toward mice:

(I) 4-(2H-naphtho[1,2-d]triazol-2-yl)-2-stilbenesulfonic acid, sodium salt

Tinopal RBS (Ciba-Geigy Corp.)

Fluorescent Brightener 46

(II) 4,4'-Bis[(4-anilino-6-morpholino-s-triazin-2-yl)amino]-2,2'-stilbenedisulfonic acid, disodium salt

Tinopal AMS (Ciba-Geigy Corp.)

(III) 4,4'-Bis[[[4-anilino-6-(2-hydroxyethyl)(methyl)amino]-s-triazin-2-yl]amino]-2,2'-stilbenedisulfonic acid, disodium salt

Tinopal 5BM (Ciba-Geigy Corp.)

(IV) 2,2'-(4,4'-biphenylylenedivinylene)dibenzenesulfonic acid, disodium salt

Compounds I,II, and III were administered in dosages of 25 and 50 mg/kg, and compound IV was administered in dosages of 5 and 10 mg/kg.

The ability of treated males to fertilize untreated females was not impaired. The numbers of implantations, resorptions, viable embryos, preimplantation losses, and mutation frequencies did not differ from those of the untreated animals.

6. Behavioral Effects

No relationships between optical brighteners and animal behavior have been reported in the literature.

C. TOXICITY TO LOWER ANIMALS

Keplinger, Fancher, Lyman, and Calandra (1974) investigated the LC_{50} values of four different optical brighteners in fish. The brighteners used in these studies were:

(I) 4-(2H-naphtho[1,2-d]triazol-2-yl)-2-stilbenesulfonic acid, sodium salt

Tinopal RBS (Ciba-Geigy Corp.)

Fluorescent Brightener 46

(II) 4,4'-Bis[4-anilino-6-morpholino-s-triazin-2-yl)amino]-2,2'-stilbenedisulfonic acid, disodium salt

Tinopal AMS (Ciba-Geigy Corp.)

(III) 4,4'-Bis[[[4-anilino-6-(2-hydroxyethyl)(methyl)amino]-s-triazin-2-yl]amino]-2,2'-stilbenedisulfonic acid, disodium salt

Tinopal 5BM (Ciba-Geigy Corp.)

(IV) 2,2'-(4,4'-biphenylylenedivinylene)dibenzenesulfonic acid, disodium salt

Compound III appeared to be the most toxic, with a twenty-four hour LC_{50} value of 120 ppm trout and 105 ppm for catfish. The twenty-four hour LC_{50} values for compound IV were 160 ppm in trout and 105 ppm for catfish. Compounds I and II showed equal activity; the twenty-four hour LC_{50} values for both trout and catfish amounted to 2000 ppm.

Ciba-Geigy Corp. (Review, 1973/1) reports that the amounts of optical brighteners which have been measured in domestic effluent in densely populated areas vary between 0.01 and 0.1 ppm. Furthermore, efficient purification plants retain more than 90% of this, so that the amounts of brightener reaching surface or ground waters would be approximately .001 to .010 ppm.

D. TOXICITY TO PLANTS

Sharma (1963) reports on chromosome breakage in alluim roots after the roots were treated with natural coumarin and some of its derivatives. Quereioli (1957) tested twenty-one derivatives of coumarin to study any toxic effects these might have toward the roots of yellow onion bulbs. A considerable degree of fragmentation of the chromosomes was noted.

Although none of the compounds used in these studies can be designated as specific optical brighteners, these studies are mentioned here because coumarin is the parent structure of several commonly used brighteners.

E. TOXICITY TO MICROORGANISMS

Blankophor FBO (Fluorescent Brightener 206), Uvitex SOF (Fluorescent Brightener 190), and Uvitex SWN (Fluorescent Brightener 140) were tested for their ability to induce petite mutants in a diphloid strain of Saccharomyces cerevisiae. Fluorescent Brightener 206 induced a high frequency of mutants when the yeast was incubated for 48 hours in its presence in darkness. Fluorescent Brighteners 140 and 190 induced photosensitization and a marked increase in petite mutants after a one-hour treatment with the brighteners in the presence of light (Gillberg, 1971).

Gillberg has since admitted that his results are irreproducible (Kilbey and Zetterberg, 1974). Kilbey and Zetterberg used the same genetic system and the same compounds as those used by Gillberg, but were unable to confirm that the suspected agents acted positively when incorporated in the growth medium of the organism. None of their several trials produced a positive result.

Darken (1964) determined that ten species of microorganisms showed increased spore germination of 159%-848% after a two-hour exposure of a 12% solution of 4,4'-bis[4-anilino-6-bis(2-hydroxyethyl)amino-s-triazin-2-ylamino]-2,2'-stilbenedisulfonic acid, disodium salt (Fluorescent Brightener 28), in 42% aqueous ethylene glycol monomethyl ether.

APPENDIX

Starting on page A-1 (follows 148), a compilation of optical brighteners has been drawn from the Colour Index, from the indices of Chemical Abstracts, and from manufacturers' data sheets. The optical brighteners are listed according to the "C.I. Fluorescent Brightener" numbers. All other information with which a correlation with the C.I. numbers could be established is included.

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METHYL CHLOROFORM, TRICHLOROETHYLENE, AND TETRACHLOROETHYLENE: SUMMARY AND CONCLUSIONS

The status of these three chlorinated hydrocarbon solvents is undergoing a change at the present time. The use of trichloroethylene is declining in industry because of the stringent regulations which are being enforced to control its use. This means that there will be bigger markets for methyl chloroform and tetrachloroethylene. They will become prominant in those areas of industrial application where trichloroethylene was formerly the solvent of choice. Tetrachloroethylene is also expected to find continuously wider application in textile manufacturing and dyeing as these industries convert from aqueous to non-aqueous systems to avoid water pollution.

The volatility of these chlorinated hydrocarbons presents a dual hazard: they are readily absorbed through the lungs and digestive tract, and they are easily transported through the air. In the literature on hand, there was little or no information specifically reporting on monitoring that is actually being carried out at the sites where these solvents are used. Very few figures are reported on actual concentrations of these compounds found during enviornmental field tests. One complete study that has been reported was done in Europe.

While methyl chloroform is considered to be the most stable and least toxic of the three solvents discussed here, it may not be considered innocuous. In fact, a system for grading these compounds according to stability or toxicity can only be valid when related to specific applications and application conditions - amount evaporating into the air during use, temperature and pressure variables, composition of contact surfaces, and duration of exposure time.

The danger of toxicity from the inhalation of these solvents is of fundamental concern. Their decomposition into toxic products, such as phosgene, occurring under use-related conditions, also presents a hazard.

The toxicity of the chlorinated hydrocarbon solvents has been established from experiments on animals and from observations of exposed humans. Acute, heavy exposures result in a depression of the central nervous system. Death may occur from respiratory and cardiac failure, although there is a wide difference between the minimum narcotic dose and the fatal dose.

All three solvents discussed in this study induce liver and kidney dysfunction following repeated, long-term exposures. However, the functioning of these organs returns to normal when the affected subjects no longer have contact with the solvents.

The metabolites of these solvents and their excretion have been carefully studied. However, the intermediate breakdown products within the body, as well as the metabolic sites, seem to remain uncertain. Since no information is available, the toxicity of the intermediates in the metabolism of these solvents cannot be assessed.

CHLORINATED HYDROCARBON SOLVENTS

(METHYL CHLORFORM, TRICHLOROETHYLENE AND TETRACHLOROETHYLENE)

I. Physical Properties

The physical and chemical properties of the chlorinated solvents methyl chloroform (1,1,1-trichloroethane), trichloroethylene, and tetrachloroethylene (perchloroethylene) qualify them for continually increasing use in industry. Their characteristic non-flammability in air, volatility, and poor solubility in water make them very useful solvents. The relatively low toxicity of methyl chloroform is a special advantage and makes it the solvent of choice in instances where another solvent might be otherwise more suitable.

All three solvents are clear, colorless liquids with the chloroform odor characteristic of the group of compounds to which they belong.

The following composite tables give the properties reported from various sources, while the single tables give data on the pure compound.

TABLE I. Chlorinated Solvents, Properties

	Methyl chloroform	Trichloroethylene	Tetrachloroethylene
Formula	$C_2H_3Cl_3$	C_2HCl_3	C_2Cl_4
Molecular weight	133.41	131.39	165.83
Melting Point °C	-50° (1)	-87° (1a)	-22° (1b)
Boiling Point °C	74-76° (1)	87° (1a)	121° (1b)
	74.1° (2)	86.9° (2)	121° (2)
Freezing Point °C	-42° (2)	-86.4° (2)	-22.4° (2)
Decomposition Temp. °C	360-440° (4)	700° (4)	700° (4)
Density	1.437 (1)	1.462 (1a)	1.462 (1b)
Flash Point	None	None	None
Relative Rate of vaporization	5.0 (3)	3.1 (3)	1.0 (3)
Solvent Power	124 (3)	129 (3)	92 (3)
Surface tension (dyne/cm^2, 20°C)	25.56 (3)	26.36 (3)	32.32 (3)
Refractive Index $^{20}_{D}$	1.4370 (1)	1.4760 (1a)	1.5056 (1b)
Vapor Pressure			
Vapor Specific Gravity (Air = 1)	4.55 (3)	4.55 (3)	5.76 (3)
Viscosity (cps, 25°C)	0.79 (3)	0.54 (3)	0.84 (3)
Autooxidation	None	Sensitive	Sensitive
Hydrolysis	Sensitive	Weak	None
Thermal Stability (without stabilizers)	Good	Good	Good

Methyl chloroform vapor pressure:

°C	mm Hg	°C	mm Hg
0	37	50	340
10	62	60	470
20	100	70	660
30	150	80	900
40	240		

(4)

Trichloroethylene vapor pressure:

°C	mm Hg	°C	mm Hg
−20	5.4	30	94
−10.8	10.8	40	146.8
0	20.1	50	212
10	35.2	60	305.7
20	57.8	86.7	760

(4)

Tetrachloroethylene vapor pressure:

°C	mm Hg	°C	mm Hg
−20.6	1	70	155.3
+2.4	5	80	226.0
13.8	10	90	319.2
26.3	20	100	438.5
40.0	41	110	591.6
50.0	67	121.2	760.0
60.0	104		

(4)

TABLE 1. Cont'd.

	Methyl Chloroform	Trichloroethylene	Tetrachloroethylene
Solubility water g/100g H_2O	$.44^{20}$	0.11^{25} 0.125^{60}(4)	0.015^{25}

(1) Aldrich Chem. Co. (97% with 3% p-dioxane)

(1a) (98%)

(1b) (Spectrophotometric grade)

(2) Hooker Chem. Co.

(3) Dyrenfurth (1972)

(4) Kirk-Othmer Encyclopedia of Chemical Technology, 5 (1964)

Table 1A - PHYSICAL AND CHEMICAL PROPERTIES OF METHYL CHLOROFORM

NAME	Methyl chloroform			STRUCTURAL FORMULA
Mole % Pur. 99.92	Ref. 1	Molecular Formula $C_2H_3Cl_3$	Molecular Weight 133.425	CH_3CCl_3

		Ref.
F.P. °C	-30.41	1
F.P. 100%		
B.P. °C 760 mm	74.096	1
100	20.35	1
30	-3.301	4
10	-21.22	4
1	-50.75	5
Pressure mm 25°C	123.37	5
t_e	925.86	5
Density g/ml 20°C	1.33899	1
d^t_4 25	1.33063	1
30	1.32224	1
a	1.37247	4
b	-0.00164	4
Ref. Index n_D 20°C	1.43789	1
25	1.43519	1
50	1.42165	1
"C"	0.4338	4
MR (Obs.)	26.152	4
MR (Calc.)	26.037	5
(nD-d/2)	0.7684	4
Dielectric		
A (-3 to 131 °C)	6.90160	1
B	1202.60	1
C	225.	5
A* (-3 to 91 °C)	1.46948	5
B*	1129.16	5
K		
c		
t_k to t_x °C		
A' to B' °C		
C'		
A'* to B'* °C		
Ac (131 to t_c °C)	7.32705	5
Bc	1524.70	5
Cc	269.86	5
Cryos. A° consts. B°	0.00558	1
t_e °C	80.61	5

		Ref.
dt/dP °C/mm 25°C	0.1829	5
BP	0.04250	4
t_e	0.03643	5
30 mm	0.5916	5
ΔHm cal/g	4.90	4
ΔHv cal/g 25°C	57.86	5
30 mm	61.12	5
BP	52.44	5
t_e	51.74	5
t_e (d, e)	51.71	5
$\Delta Hv/T_e$	19.51	5
d (-3 to 81 °C)	60.75	5
e	0.1122	5
d' (to °C)		
e'		
d_c g/ml		
v_c ml/g		
t_c °C	266.	5
P_c mm	30274.	5
PV/RT 25°C	0.9867	5
30 mm	1.0000	5
BP	0.9467	5
t_e	0.9405	5
t_c		
ΔHc kcal/m		
ΔHf		
ΔFf		
Viscosity centistokes η 20 °C	0.6282	1
40	0.4899	1
60	0.3962	1
80	0.3612	1
B^v (10 to 50 °C)	495.84	4
A^v	Σ.1070	4
(B^v) (50 to 90 °C)	236.35	4
(A^v)	Σ.8886	4
c_p liq. °K		
c_p vap. °K		
c_v vap.		

		Ref.
f, g, h (to °K)		
f', g', h' (to °K)		
m, n, o (to °K)		
m', n', o' (to °K)		
Surface tension dynes/cm. 20°C	25.39	1
γ 30	24.11	1
40	22.87	1
Parachor [P] 20°C	223.7	4
30	223.8	4
40	223.9	4
Sugd.	223.8	5
Exp. L.1.%/wt. u. Dispersion		
Flash Point °C Fire Point		
M Spec. Ultra V. X-Ray Dif. Infrared		
Solubility in + Acetone, Carbon tet., Benzene, Ether, n-Heptane, Ethanol, Water, Water in		

$T_R = 0.75\,T_c$

+ grams/100 grams solvent

REFERENCES: 1-Dow 2-API 3-Lit. 4-Calc. from det. data 5-Calc. by formula

SOURCE: Dow, dist.

PURIFICATION: Dow, dist.

Source: ADVANCES IN CHEMISTRY SERIES NUMBER 22

Table 1B - PHYSICAL AND CHEMICAL PROPERTIES OF TRICHLOROETHYLENE

NAME	1,1,2-Trichloroethylene			STRUCTURAL FORMULA
Mole % Pur.	Ref.	Molecular Formula C_2HCl_3	Molecular Weight 131.399	$CCl_2=CHCl$

		Ref.			Ref.			Ref.
F.P. °C			dt/dP			f to		
F.P. 100%			°C/mm			g °K		
B.P. °C			25°C	0.2890	5	h		
760 mm	87.08	1	BP	0.04369	5	f' to		
100	31.54	4	t_e	0.0359	5	g' °K		
30	6.90	5	30 mm	0.6178	5	h'		
10	-11.85	5	ΔHm cal/g			m to		
1	-42.89	5	ΔHv cal/g			n °K		
Pressure			25°C	62.33	5	o		
mm 25°C	74.31	5	30 mm	64.02	5	m' to		
t_e	975.52	5	BP	56.43	5	n' °K		
Density			t_e	55.61	5	o'		
g/ml 20°C	1.46422	1	t_e (d,e)	55.62	5	Surface tension		
d_4^t 25	1.45541	1	ΔHv/T_e	19.81	5	dynes/cm. 20°C	29.28	1
60	1.39501	1	d 7 to	64.67	5	γ 30	27.94	1
a	1.49948	4	e 96 °C	0.0946	5	40	26.76	1
b	-0.00174	4	d' to			Parachor [P]		
Ref. Index			e' °C			20°C	208.7	4
n_D 20°C	1.47734	1	d_c g/ml	0.513	5	30	208.8	4
25	1.47457	1	v_c ml/g	1.950	5	40	209.0	4
50	1.46056	1	t_c °C	298.	5	Sugd.	212.8	5
"C"	0.4302	4	P_c mm	36876.	5	Exp. L.l.%/wt.		
MR (Obs.)	25.37	4	PV/RT			u.		
MR (Calc.)	25.57	5	25°C	0.9957	5	Dispersion		
(nD-d/2)	0.74523	4	30 mm	1.0000	5	Flash Point °C		
Dielectric			BP	0.9578	5	Fire Point		
A 7 to	7.02808	4	t_e	0.9507	5	M Spec.		
B 155 °C	1315.0	4	t_c	0.265	5	Ultra V.		
C	230.	4	ΔHc kcal/m			X-Ray Dif.		
A* 7 to	1.54642	5	ΔHf			Infrared		
B* 106 °C	1230.2	5	ΔFf			Solubility in +		
K			Viscosity centistokes			Acetone		
c			η 20 °C	0.3844	1	Carbon tet.		
t_k to			40	0.3291	1	Benzene		
t_x °C			60	0.2867	1	Ether		
A' to			80	0.2553	1	n-Heptane		
B' °C			B^v 10 to	311.03	4	Ethanol		
C'			A^v 70 °C	2.52395	4	Water		
A'* to			(B^v) to			Water in		
B'* °C			(A^v) °C					
Ac 155 to	7.4675	5	c_p liq. °K					
Bc t_c °C	1675.	5	c_p vap. °K					
Cc	280.	5	c_v vap.					
Cryos. A* consts. B*								
t_e °C	95.60	5						

$T_R = 0.75\ T_c$

+ grams/100 grams solvent

REFERENCES: 1-Dow 2-API 3-Lit. 4-Calc. from det. data 5-Calc. by formula

SOURCE: Dow

PURIFICATION: Distillation

Source: ADVANCES IN CHEMISTRY SERIES NUMBER 22

Table 1C - PHYSICAL AND CHEMICAL PROPERTIES OF TETRACHLOROETHYLENE

NAME	Perchloroethylene			STRUCTURAL FORMULA
Mole % Pur.	Ref.	Molecular Formula C_2Cl_4	Molecular Weight 165.848	$CCl_2=CCl_2$

		Ref.
F.P. °C		
F.P. 100%		
B.P. °C 760 mm	120.97	1
100	60.97	4
30	34.37	4
10	14.02	5
1	-20.12	5
Pressure mm 25°C	18.47	5
t_e	1086.	5
Density g/ml 20°C	1.62272	1
d_4^t 25	1.61446	1
30	1.60590	4
a	1.65599	4
b	-0.00166	4
Ref. Index n_D 20°C	1.50534	1
25	1.50284	1
30	1.50004	4
"C"	0.4095	4
MR (Obs.)	30.34	4
MR (Calc.)	30.437	5
(nD-d/2)	0.69417	4
Dielectric		
A (34 to 187 °C)	7.02003	4
B	1415.5	4
C	221.	4
A* (34 to 144 °C)	1.58865	5
B*	1321.5	5
K		
c		
t_k to		
t_x °C		
A' (25 to 34 °C)	7.41073	5
B'	1622.1	5
C'	239.	5
A'* 25 to	1.96901	5
B'* 34 °C	1518.6	5
Ac (167 to t_c °C)	7.4489	5
Bc	1787.	5
Cc	271.	5
Cryos. A* consts. B*		
t_e °C	134.28	5

		Ref.
dt/dP °C/mm 25°C	1.0102	5
BP	0.04721	5
t_e	0.0357	5
30 mm	0.6670	5
ΔHm cal/g		
ΔHv cal/g 25°C	57.09	5
30 mm	56.65	5
BP	50.0	5
t_e	48.96	5
t_e (d, e)	48.98	5
$\Delta Hv/T_e$	19.93	5
d (34 to 134 °C)	59.29	5
e	0.0768	5
d' (25 to 34 °C)	58.27	5
e'	0.0472	5
d_c g/ml	0.573	4
v_c ml/g	1.745	4
t_c °C	340.	5
P_c mm	33687.	5
PV/RT 25°C	1.0000	5
30 mm	1.0000	5
BP	0.9672	5
t_e	0.9580	5
t_c	0.255	5
ΔHc kcal/m		
ΔHf		
ΔFf		
Viscosity centistokes η 20 °C	0.54976	1
40	0.45702	1
60	0.39347	1
80	0.34061	1
B^v (10 to 90 °C)	353.2	4
A^v	2.53223	4
(B^v) to		
(A^v) °C		
c_p liq. °K		
c_p vap. °K		
c_v vap.		

			Ref.
f, g, h	to °K		
f', g', h'	to °K		
m, n, o	to °K		
m', n', o'	to °K		
Surface tension dynes/cm. 20°C		31.33	1
γ 30		30.81	1
40		30.20	1
Parachor [P] 20°C		241.8	4
30		243.3	4
40		244.6	4
Sugd.		250.0	5
Exp. L.1.%/wt.			
u.			
Dispersion			
Flash Point °C			
Fire Point			
M. Spec.			
Ultra V.			
X-Ray Dif.			
Infrared			
Solubility in +			
Acetone			
Carbon tet.			
Benzene			
Ether			
n-Heptane			
Ethanol			
Water			
Water in			

$T_R = 0.75\,T_c$

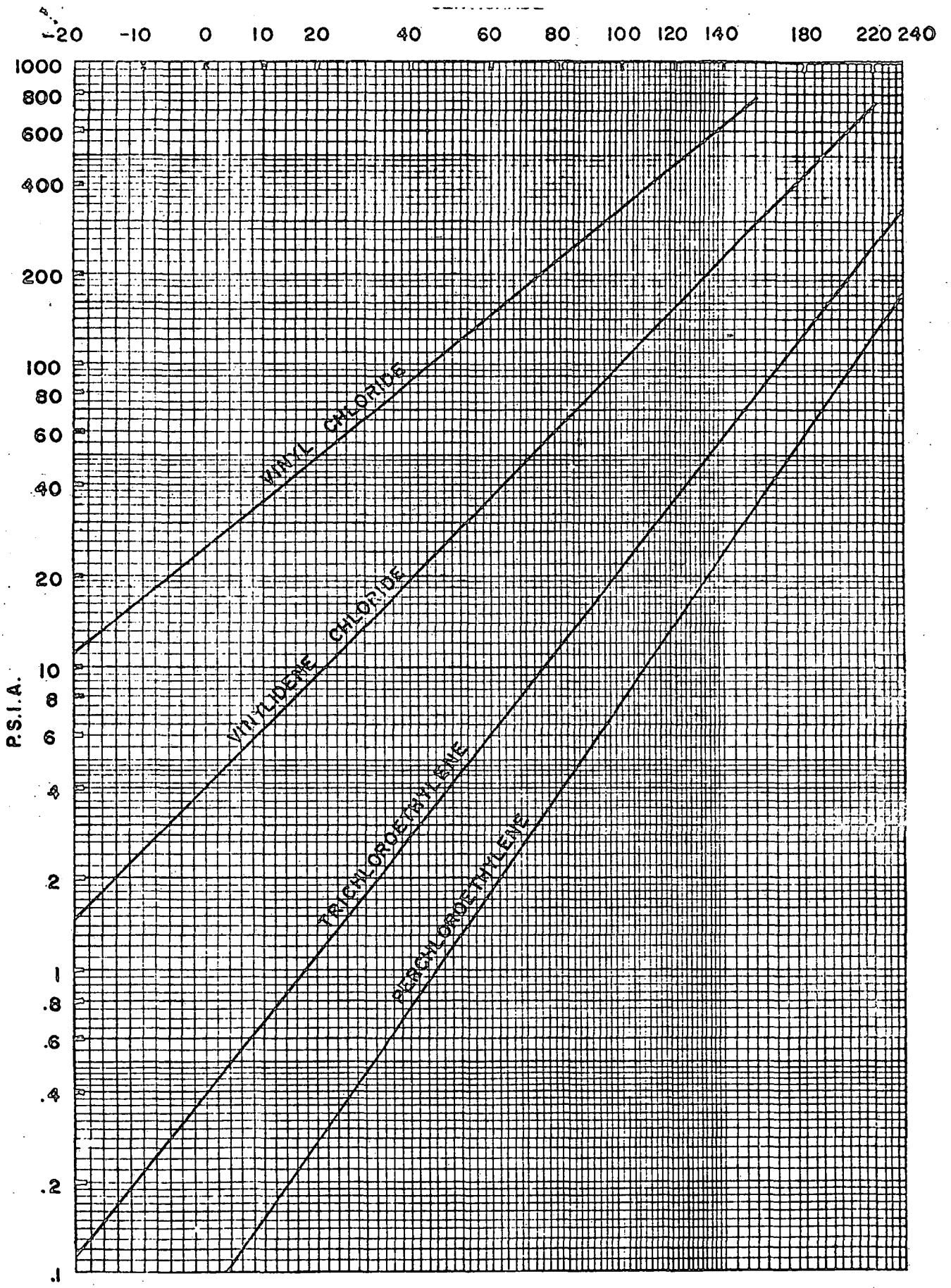
+ grams/100 grams solvent

REFERENCES: 1-Dow 2-API 3-Lit. 4-Calc. from det. data 5-Calc. by formula

SOURCE: Dow

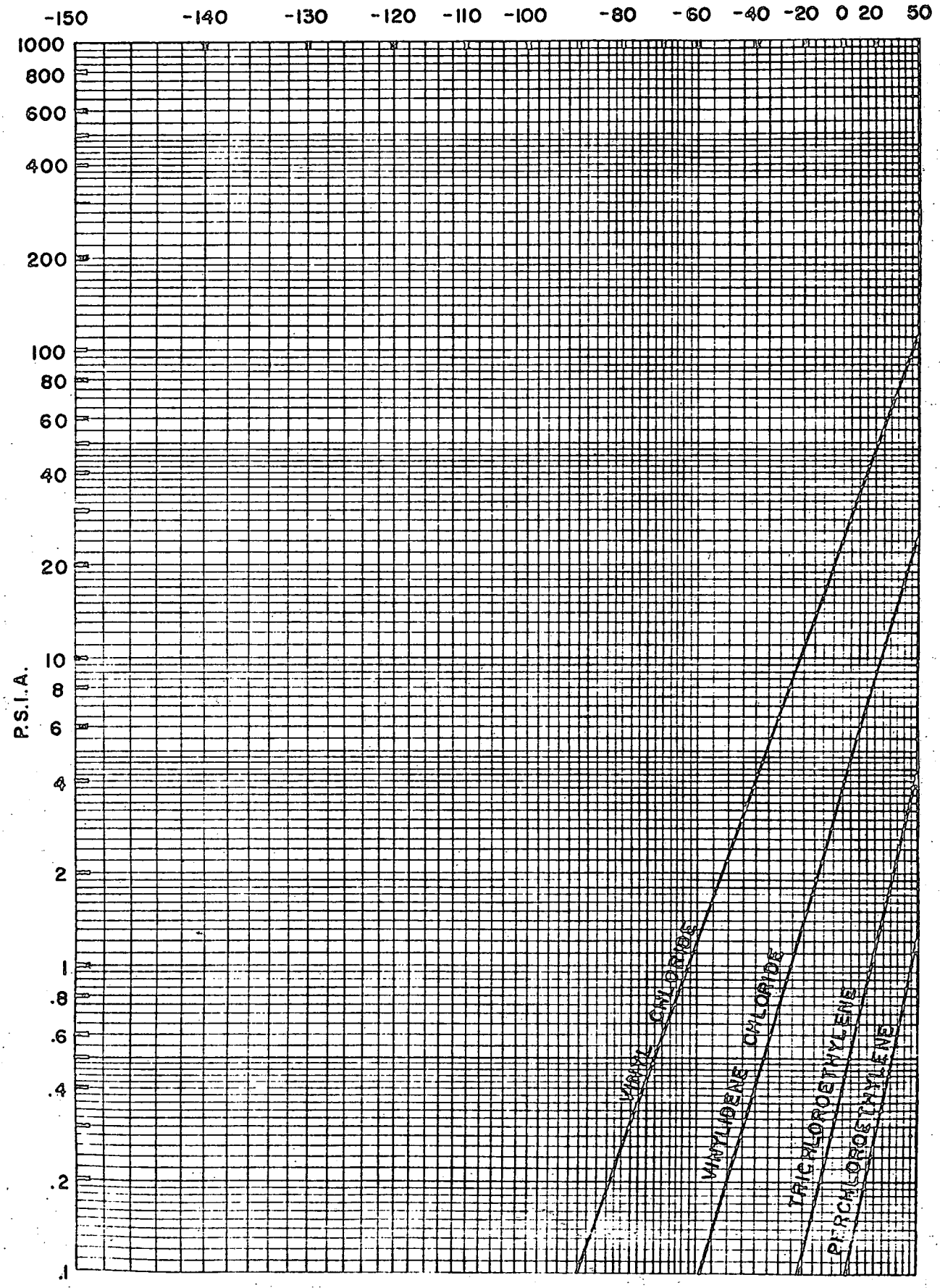
PURIFICATION: Distillation

Source: ADVANCES IN CHEMISTRY SERIES NUMBER 22



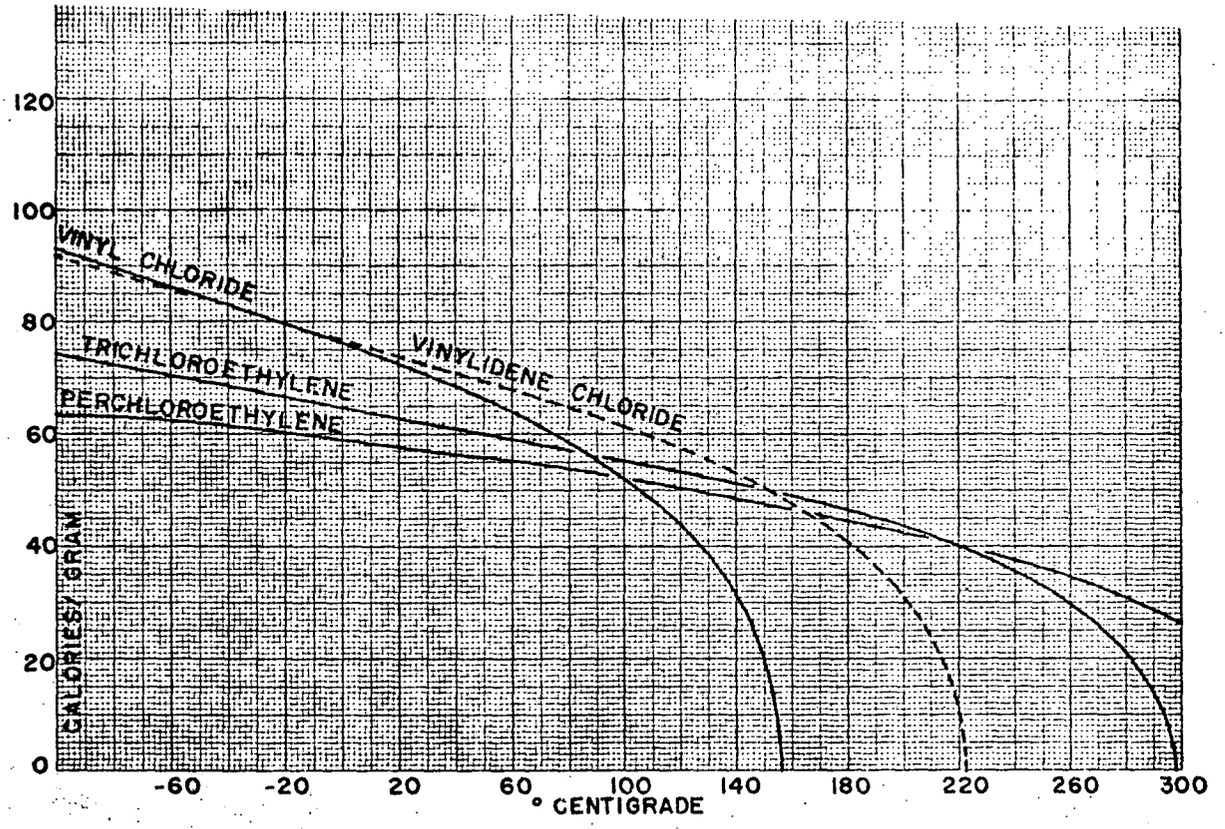
vapor pressure over a range of −20° C to +240° C.

Source: GALLANT, 1966

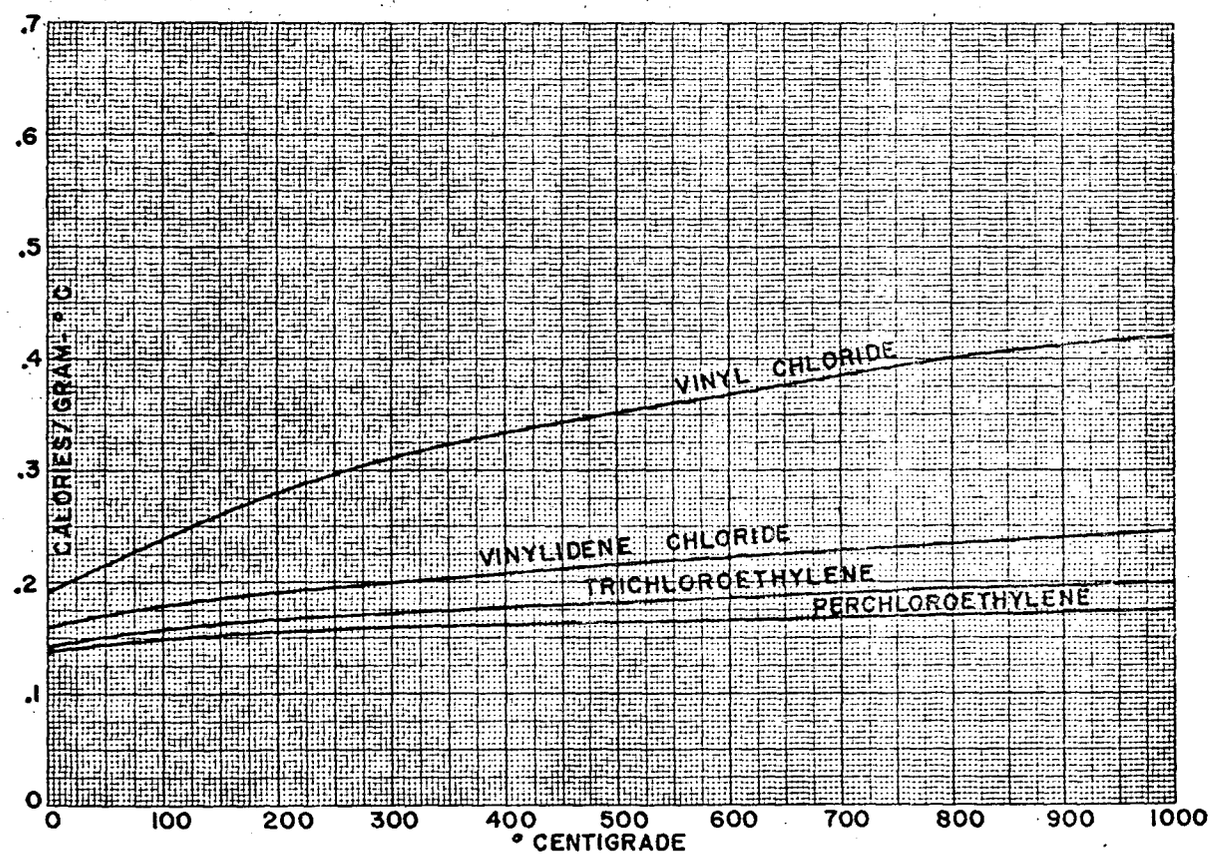


vapor pressure over a range of −90° C to +50° C.

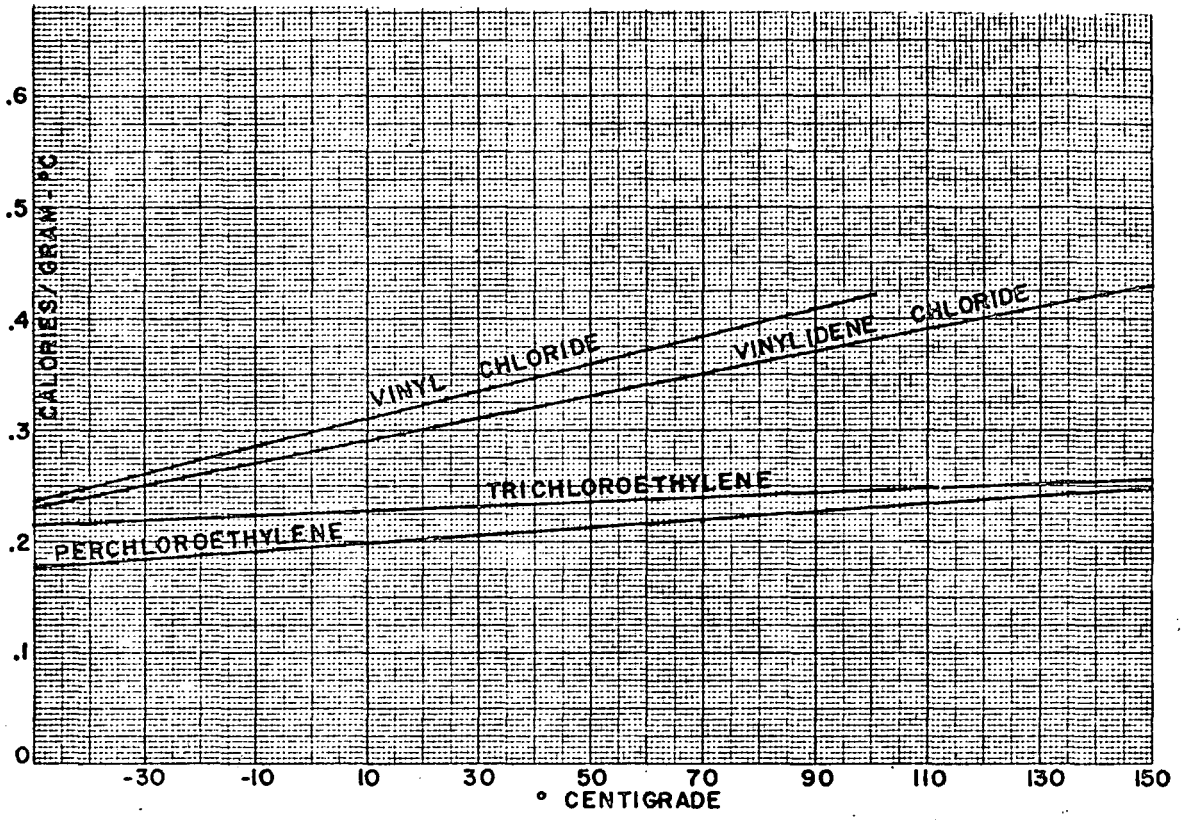
Source: GALLANT, 1966



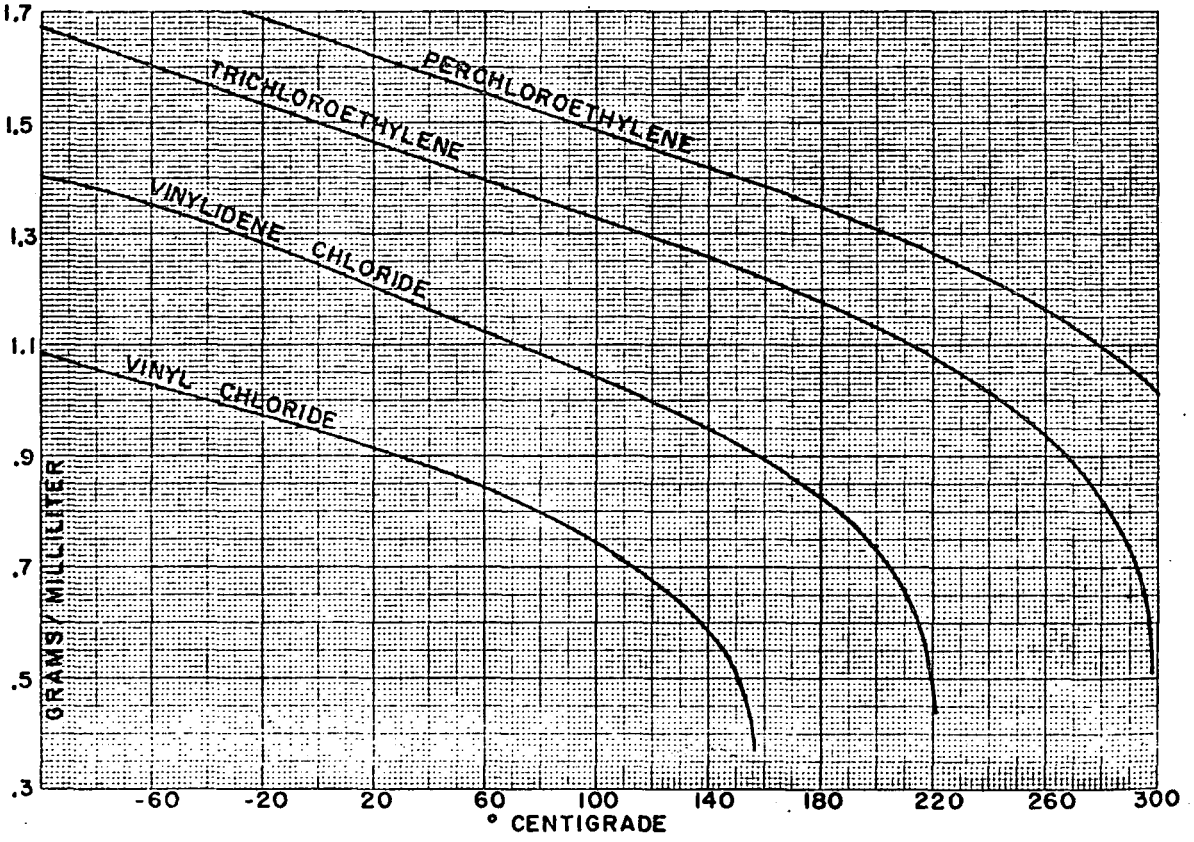
heat of vaporization over a range of −60° C to +300° C.



Source: GALLANT, 1966 vapor heat capacity over a range of 0° C to +1,000° C.

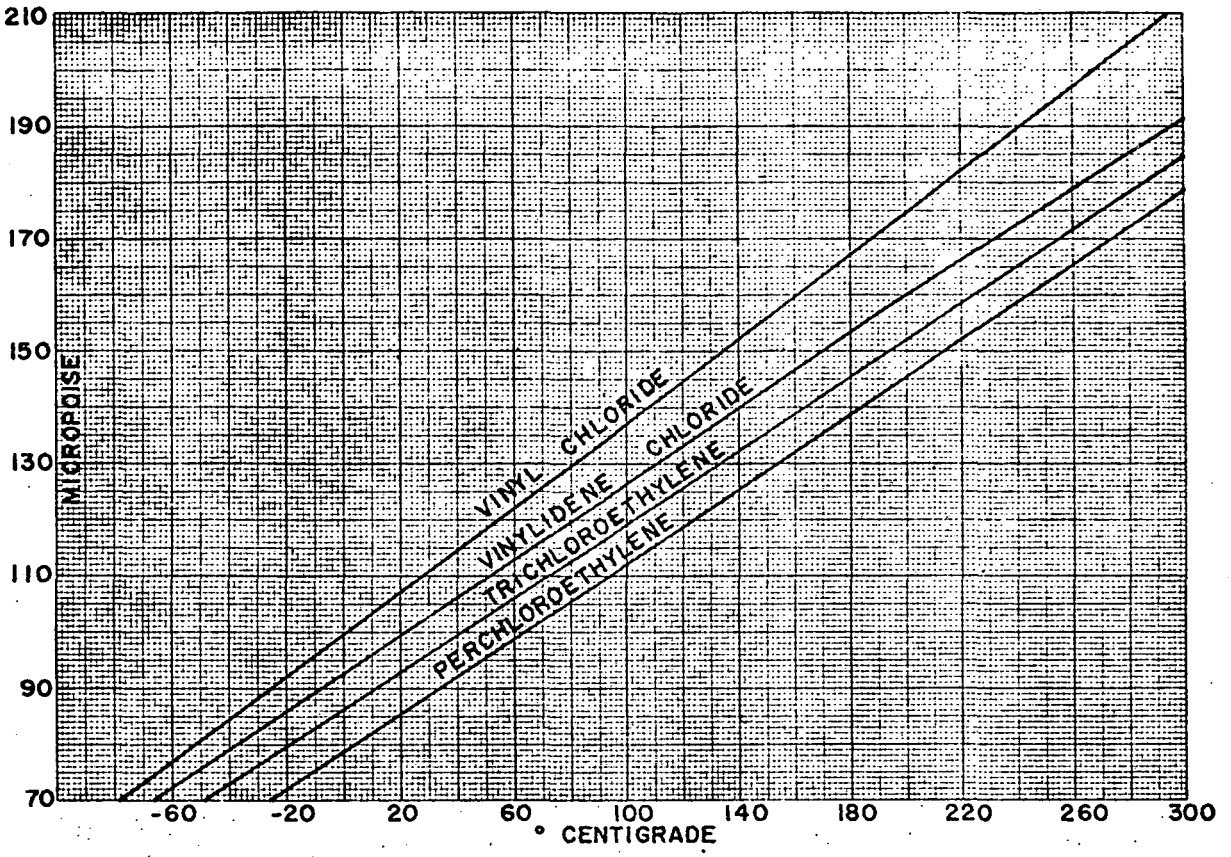


liquid heat capacity over a range of −30° C to +150° C.

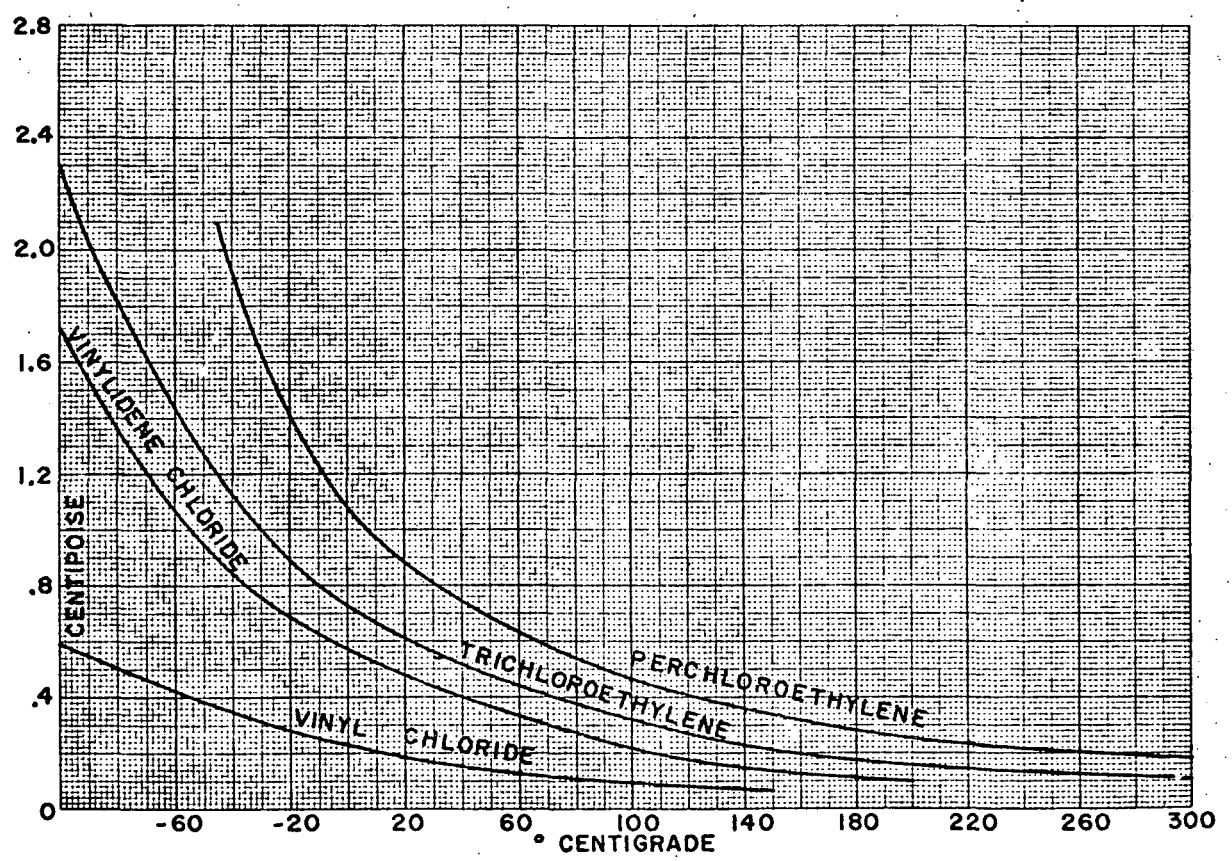


liquid density over a range of −60° C to +300° C.

Source: GALLANT, 1966

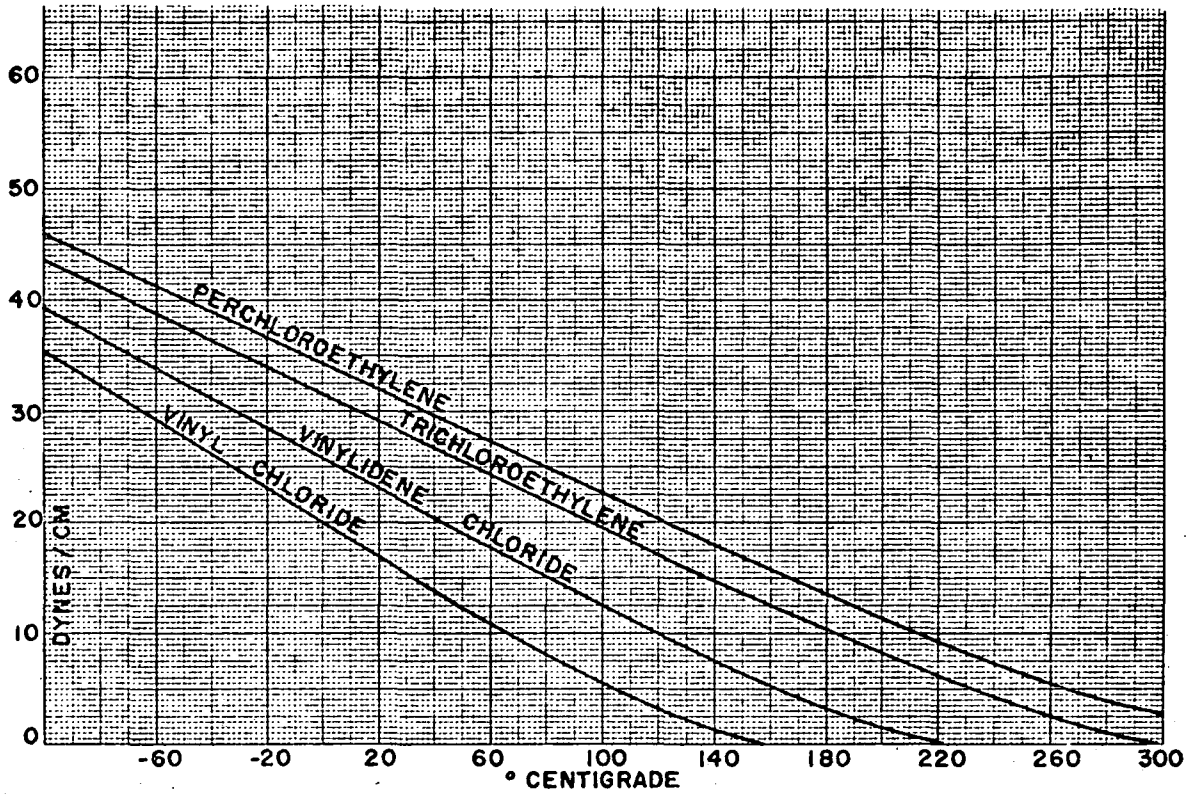


vapor viscosity over a range of −60° C to +300° C.

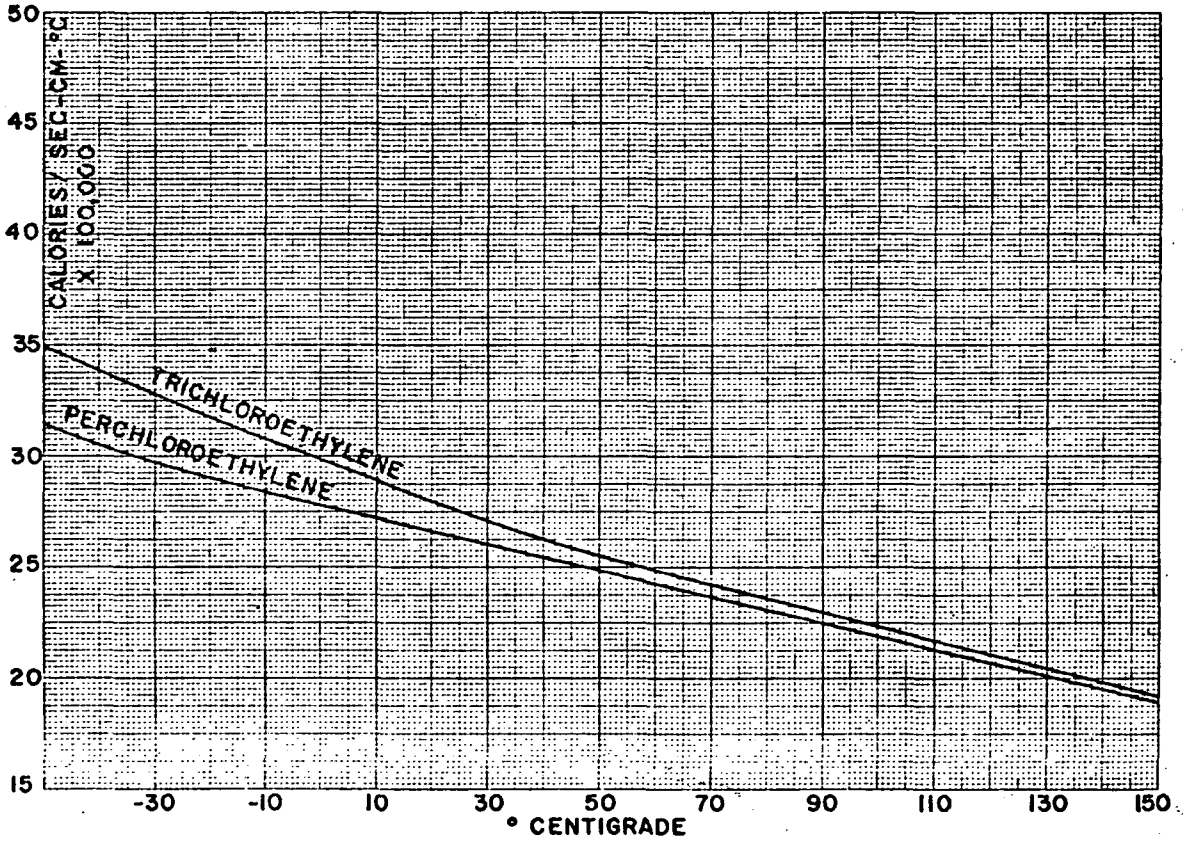


Source: GALLANT, 1966

liquid viscosity over a range of −60° C to +300° C.



surface tension over a range of −60° C to + 300° C.



liquid thermal conductivity over a range of −30° C to +150° C.

Source: GALLANT, 1966

TRICHLOROETHYLENE

U.S. Federal Specification O-T-634a, Technical Grade Dated April 17, 1956

Chemical and Physical Requirements

General (Type I and II)

Appearance	Clear and free of suspended matter or sediment
Specific Gravity 20°/20°C	1.450 - 1.475
Acidity as HCl:	0.01% Max.
Alkalinity as NaOH:	0.01% Max.
Water Content:	No cloud at 0°C
Copper Corrosion and Free Chlorine:	Must pass government test
Color:	Shall not be darker than a solution containing 0.0045 gm potassium dichromate in one liter of distilled water.

	Type I	Type II
Odor:	No residual odor	--
Non-Volatile:	0.004 gm/100 ml Max.	0.020 gm/100 ml Max.
Spot Test:	No spot or stain	Faintly discernible spot or stain
Distillation Range:		
Initial Boiling Point	86.0°C	85.0°C
At Least 95%	--	Below 90.0°C
End Point:	90.0°C	95.0°C
Acidity as HCl:	--	0.02% Max.

Source: Chemical Economics Handbook

TETRACHLOROETHYLENE

U.S. Federal Specification O-P191a Technical Grade, Dated September 23, 1959, and Amendment 1, Dated February 21, 1961:

Appearance:	Clear and free of suspended matter or sediment.
Color:	Shall not be darker than a solution containing 0.0045 gm. potassium dichromate in one liter of distilled water.
Odor:	Characteristic, no residual odor.
Specific Gravity 20°/20°C:	1.615 - 1.630
Non-Volatile Matter:	0.016 gm/100 ml. max.
pH at 25°C:	5.0 min.
Distillation Range:	118 - 124°C
Acid Acceptance:	
Amine	0.01 max.
Non-amine	0.08 - 0.12
Spot Test:	No spot or stain
Water Content:	No cloud at 0°C
Copper Corrosion and Free Chlorine:	Must pass government tests

Source: Chemical Economics Handbook

II. PRODUCTION

A. Methyl Chloroform

The following are the largest reported manufacturers of methyl chloroform in the U.S.

Company and Location	Annual Capacity As of September 1972 (Millions of Pounds)	Raw Material
Dow Chemical U.S.A. Freeport, Texas	340	vinyl chloride
Ethyl Corporation Industrial Chemicals Division Baton Rouge, Louisiana	50	vinyl chloride
PPG Industries, Inc. Industrial Chemicals Division Lake Charles, Louisiana	175	vinylidene chloride
Vulcan Materials Company Chemicals Division Geismar, Louisiana	65	ethane
Total	630	

Source: Chemical Economics Handbook

The overall reactions for methyl chloroform production may be represented as follows:

$$CH_2 = CHCl + Cl_2 \rightarrow CH_3CCl_3$$

and

$$CH_2 = CCl_2 + HCl \rightarrow CH_3CCl_3$$

No figures on methyl chloroform production are available prior to 1966.

Methyl Chloroform (Millions of Pounds)

	Production	Sales
1966	242.9	249.7
1967	--	269.7
1968	299.4	288.1
1969	324.3	298.9
1970	366.3	327.4
1971	374.6	341.3
1972	--	--
1973 (p)	537.3	--
Jan. 1974 (p)	45.2	--

Source: United States Tariff Commission

United States Production and Sales of Miscellaneous Chemicals

(p) Preliminary Report S.O.C. Series C/P-74-1

Rule 66 which went into effect in Los Angeles County in 1967 has had a favorable impact on the methyl chloroform market. The restricting of trichloroethylene caused 50% of the vapor degreasing industry in Los Angeles to switch to other chlorinated solvents. Also, late in 1971, Dow announced that it was producing vinylidene chloride directly from methyl chloroform, a change which adds approximately 8-10 million pounds per month to reported methyl chloroform production (Chemical Economics Handbook).

The Dow Chemical Co. states that methyl chloroform has the best health and safety picture and is also more readily recovered than other chlorinated solvents. It could introduce a savings in consumption of 20-30%. Dow expects methyl chloroform to grow by 9-10% per year through 1975, and 5-8% per year after that (Chemical Week, November 15, 1972).

B. Trichloroethylene

During the first part of 1972, the Detrex Chemical Industries, Inc. closed their plant at Ashtabula, Ohio, which had a production of 100 million pounds per year of trichloroethylene. In May, 1972, du Pont closed its Electrochemicals Department plant at Niagara Falls, N.Y., where 250 million pounds of trichloroethylene were produced per year.

The overall reactions for trichloroethylene manufacture may be represented as follows:

$$HC \equiv CH + 2Cl_2 \rightarrow CHCl_2 + CHCl_2$$

$$2CHCl_2\ CHCl_2 + Ca(OH)_2 \rightarrow 2CHCl = CCl_2 + CaCl_2 + 2H_2O$$

$$CHCl_2\ CHCl_2 \xrightarrow[\text{Pyrolysis}]{} CHCl = CCl_2 + HCl$$

$$CH_2ClCH_2Cl + 2Cl_2 \rightarrow CHCl = CCl_2 + 3HCl$$

As of September, 1972, the following five companies were reported as producers of trichloroethylene in the United States:

Company and Location	Annual Capacity As of September 1972 (Millions of Pounds)	Raw Material
Dow Chemical U.S.A.[a]		
Freeport, Texas	150	Ethylene
Diamond Shamrock Chemical Company[b]		
Electric Chemicals Division		
Deer Park, Texas	60	Ethylene
Ethyl Corporation		
Industrial Chemicals Division		
Baton Rouge, Louisiana	50	Ethylene
Hooker Chemical Corporation[c]		
Industrial Chemicals Division		
Tacoma, Washington	30	Acetylene
Taft, Louisiana	40	Acetylene
PPG Industries, Inc.[d]		
Industrial Chemical Division		
Lake Charles, Louisiana	200	Ethylene
Total	530	

a. An additional 50 million pounds per year unit was closed in late 1971.

b. Believed to be producing only small quantities (production was not reported to the U.S. Tariff Commission in 1971 or in the first six months of 1972). Capacity of the plant will be expanded by April 1973.

c. A 60 million pounds per year acetylene-based trichloroethylene plant at Niagara Falls, New York, was closed in early 1972.

d. Expanding to 280 million pounds per year by the end of 1973.

Source: Chemical Economics Handbook.

The following data on production and sales have been taken from the Chemical Economics Handbook and from the United States Tariff Commission TC Publication C/4 for 1971 and Preliminary Report S.O.C Series C/P-74-1 of the same source for 1973. Preliminary figures are indicated by (p).

Trichloroethylene (Millions of Pounds)

	Production	Sales
1935	12	—
1936	21	—
1937	33	—
1938	27	—
1939	34	—
1940	55	—
1941	(82)	—
1942	130	—
1943	(150)	—
1944	(170)	—
1945	185	—
1946	(186)	—
1947	(188)	—
1948	190	—
1949	(205)	—
1950	(215)	—
1951	(250)	233.2
1952	270.5	241.8
1953	323.3	287.7
1954	296.8	252.4
1955	316.2	284.5
1956	346.1	303.2
1957	337.7	292.2
1958	295.1	243.5
1959	360.2	302.2
1960	352.8	298.8
1961	309.2	325.8
1962	356.1	347.9
1963	368.2	362.6
1964	370.5	370.1
1965	434.5	428.1
1966	480.2	462.9
1967	490.0	472.7
1968	519.1	527.6
1969	596.8	561.5
1970	610.8	568.9
1971	514.8	532.4
1972	(438.0)	—
1973 (p)	450.5	—
Jan. 1974 (p)	38.6	—

Producers are curtailing any expansions in trichloroethylene production since Los Angeles' Rule 66 placed trichloroethylene on the list of restricted solvents. Similar types of legislation have been passed in several states.

Diamond Shamrock sees a gradual drop in trichloroethylene volume, conceding it could decline as much as 25-30% by 1975 if all agencies decide on rigorous enforcement. Dow sees trichloroethylene volume going from 600 million pounds per year in 1970 to 400 million pounds per year in 1975, with the drop continuing (Chemical Week, November 15, 1972).

C. Tetrachloroethylene

Of the companies reported as producers of tetrachloroethylene in the United States as of September, 1972, Diamond Shamrock, du Pont, and PPG expected to have undergone considerable expansion in tetrachloroethylene production by the end of 1973.

It is estimated that about 20% of the tetrachloroethylene produced is from the acetylene-chlorine method. The majority, however, is produced as follows:

$$CH_2ClCH_2Cl + 3Cl_2 \rightarrow Cl_2C = CCl_2 + 4HCl$$

$$C_3H_8 + 8Cl_2 \rightarrow CCl_4 + Cl_2C = CCl_2 + 8HCl$$

$$2C_3H_6 + 16\ Cl_2 \rightarrow 4CCl_4 + Cl_2C = CCl_2 + 12\ HCl$$

Following is a list of the major producers in the United States.

Tetrachloroethylene Capacity

Company and Location	As of September 1972 (Millions of Pounds)	Raw Material
Diamond Shamrock Chemical Company		
Electro Chemicals Division		
Deer Park, Texas	100	Ethylene dichloride
Dow Chemical U.S.A.		
Freeport, Texas	120	Various
Pittsburg, California	20	Various
Plaquemine, Louisiana	105	Various
E. I. du Pont de Nemours & Co., Inc.		
Electrochemicals Department		
Corpus Christi, Texas	0	
Ethyl Corporation		
Industrial Chemicals Division		
Baton Rouge, Louisiana	75	Ethylene dichloride
Hooker Chemical Corporation		
Industrial Chemicals Division		
Tacoma, Washington	10	Calcium carbide acetylene generated by Hooker
Taft, Louisiana	35	Acetylene generated by Union Carbide Corporation
PPG Industries, Inc.		
Industrial Chemical Division		
Lake Charles, Louisiana	160	Ethylene dichloride
Stauffer Chemical Company		
Industrial Chemical Division		
Louisville, Kentucky	70	Various
Vulcan Materials Company		
Chemicals Division		
Geismar, Louisiana	150	Various
Wichita, Kansas	40	Various
Total	885	

Source: Chemical Economics Handbook

The following data have been taken from the Chemical Economics Handbook, from the United States Tariff Commission TC Publication 614 for 1971 and from Preliminary Report S.O.C. Series C/P-74-1 of the same source for 1973. Preliminary figures are indicated by (p).

Tetrachloroethylene (Millions of Pounds)

	Production	Sales
1940	12	—
1941	(13)	—
1942	15	—
1943	53.0	—
1944	75.1	—
1945	60	—
1946	(63)	—
1947	(65)	—
1948	70	—
1949	(80)	—
1950	(93)	—
1951	109.8	103.0
1952	105.7	97.6
1953	152.9	136.4
1954	158.0	140.6
1955	177.9	160.5
1956	185.6	169.0
1957	196.6	168.6
1958	187.2	162.3
1959	203.0	186.0
1960	209.4	187.2
1961	225.1	225.4
1962	320.5	307.7
1963	325.1	278.1
1964	365.7	335.6
1965	429.4	385.0
1966	462.7	424.8
1967	533.0	468.7
1968	636.5	567.0
1969	635.3	611.6
1970	706.9	640.2
1971	704.7	653.9
1972 (p)	(745)	—
1973 (p)	693.8	—
Jan. 1974 (p)	65.8	—

Tetrachloroethylene profits from the restriction on trichloroethylene, although methyl chloroform is favored in metal degreasing because of its lower toxicity.

The dry cleaning market is expected to increase its consumption of tetrachloroethylene at 4-5% per year through 1975. It is estimated that the perchloroethylene consumption for industrial dry cleaning will increase from about 90 million pounds in 1971 to 200 million pounds by 1975 (Chemical Economics Handbook).

III. USES

The chlorinated hydrocarbon solvents find their most widespread applications as alternatives to water-surfactant systems in dry-cleaning and metal degreasing (Carbonnier, 1967; Streeb, 1972; Weitbrecht, 1965; Willard, 1972).

The use of organic solvents as substitutes for water as a medium for dyeing fabric could eliminate much of the liquid dye wastes from textile plants, since less actual waste remains after dyeing and this smaller amount could be used in a variety of ways. This would have an immediate effect on the water pollution problem. Tetrachloroethylene is the subject of much research in this area (Byeland, 1971; Fielding, 1972; Furness, 1971; Gebert, 1971).

Methyl chloroform is the principal solvent in wet cleaning applications. Its use as a vapor degreaser is expected to increase by 10% per year as trichloroethylene undergoes further restrictions. The low toxicity of methyl chloroform, its good evaporation rate, lack of flash and fire points (in air), and moderately high vapor pressure qualify it as a solvent and carrier for many of the active materials used in aerosols, specifically in spot removers. It is used to raise the apparent flash point in flammable petroleum solvents and is used as a coolant in cutting oils, printing inks, and shoe polishes. It is a resin solvent in adhesives and is used in the textile industry for processing and finishing. Dow Chemical produces vinylidine chloride directly from methyl chloroform.

While trichloroethylene has incurred disfavor as a solvent in vapor degreasing because of its escape into the atmosphere (Dale, 1972; Greve, 1971), it may find wide application in non-aqueous textile processing and finishing (Dyhrenfurth, 1972; Willard, 1972).

Trichloroethylene is used as an inhalation anaesthetic during parturition and in dentistry (Huff, 1971; Kloos, 1966). It is used in the extraction of hops and of soybean oil meal (Kloos, 1966; Pritchard, 1956).

Tetrachloroethylene is the leading dry-cleaning solvent and is the subject of much research in the dyeing industry (Byland, 1971; Fielding, 1972; Furners, 1971; Gebert, 1971). It is used in both cold-cleaning and vapor degreasing of metals, as a solvent for silicones, and as an intermediate in the synthesis of fluroocarbons 113, 114, 115, 116.

In the past, tetrachloroethylene has been used in treating fresh and dried fruits (Deshusses, 1955) and in controlling rot-producing mold on strawberries and on other fresh fruit (Mapers, 1954). More recently, the brominated hydrocarbons have replaced tetrachloroethylene in these processes.

It has been applied medically as an antihelmetic (Jung, 1960; Mackie, 1955). There are no references to this application in the more recent literature,

Representative Commercial Products Containing Trichloroethylene

Brush Top Spot Remover, Regular**
(Product Sales Co.)

Espersol 2530 (xylene)	87%
Trichloroethylene	10
Perchloroethylene	1.5
Methylene chloride	1.5

Brush Top Spot Remover, Super**
(Product Sales Co.)
100% chlorinated solvents

Triethane (1,1,1-trichloroethane)	50%
Trichloroethylene	25
Perchloroethylene	10
Methylene chloride	5

Carbona Cleaning Fluid
(Carbona Products Co.)

Trichloroethylene	44%
Petroleum hydrocarbons	56

Carbona No. 10 Special Spot Remover
(Carbona Products Co.)

1,1,1-trichloroethane	10%
Trichloroethylene	40
Petroleum hydrocarbons	50

Carbona Spray Spot Remover
(Carbona Products Co.)
Trichloroethylene
1,1,1-Trichlorethane
Cab-O-Sil
Freon 12

Crater 2X and 5X Fluid
(Texaco, Inc.)
Petroleum lubricating oil
Trichloroethylene
Pine tar

DuPont Dry Clean
(du Pont)
Trichloroethylene

Dux
Water Repellent
(Detrex Corp.)

Piccotex 120 Solution (synthetic resin)	25%
Wax (paraffin)	
Trichloroethylene	

Glamorene Dry Cleaner for Rugs
(Formerly Glamorene Wool Rug Cleaner)
(Glamorene Products Corp.)
Chlorinated hydrocarbon
(trichloroethylene)
Petroleum distillate
Wool flour

Glamorene Rug Cleaner
(Glamorene Products Corp.)
Trichloroethylene
Ethylene dichloride
Heavy naphtha

Helmac Spot Pic-Up
Aerosol spot remover
(Helmac Products Corp.)
Perchlorethylene
Methylene chloride
Trichloroethylene

HH Tree Wound Healer
Protective seal for pruned and damaged tree and shrubs
(Hubbard-Hall Chem. Co.)
Asphaltum
Petroleum oils
Phenylmercury oleate
Allantoin
Inert ingredients:
Dichlorodifluoromethane
Trichloroethylene
Methylene chloride

Instant Chimney Sweep
Aerosol spray application
(Miracle Adhesives)

	%w/w
Trichloroethylene	34
Active chemicals	41
Propellant (Freon)	25

Joy Solvent**
(Joy Chem. Inc.)
Trichloroethylene

Kwik Kleen Drug Shampoo*
Dry Shampoo
(Royal Bond, Inc.)
Trichloroethylene

Lash Bath
Cleanser for false eyelashes
(Revlon)
Naphtha
Trichloroethylene

O'Cedar Sea-Spray**
(O'Cedar)
Methylene chloride
Trichloroethylene
Cellosolve acetate
Synthetic detergents
Wax
Freon propellent

Perm-A-Clor NA
(Detrex Corp.)
Trichloroethylene

Sears Air Freshener

Sears Odor Neutralizer
(Sears, Roebuck, & Co.)

	26-725
Essential oils	55.2%
Perfume	10.4
Trichloroethylene	34.5

Spot Chief**
Aerosol ring-free spot remover
(White Frost, Inc.)
Trichloroethylene
Perchlorethylene
Solvent 310 (petroleums

Solvent 310 (petroleum solvent)
Paradichlorobenzene
Lanolin
1,1,1-trichloroethane
Freon 12

Surfisan Spray*
Surface disinfection, preservation and deodorizing
(Royal Bond, Inc.)
Chloroform
Kerosene
Camphor
Trichloroethylene

Triad Metal Cleaner
Trichloroethylene

Triad Metal Polish
Trichloroethylene

Trichlor
Solvent
(P.P.G. Industries, Chem. Div.)
Trichloroethylene 100%

Tri-Clene Dry Clean
Trichloroethylene

*No longer contains trichloroethylene but listed since some products may still be in use.
No longer marketed, but some may still be in use.
The above product descriptions are not to be construed as current or accurate since changes in product composition are being made continually by manufacturers.

Source: Huff, 1971

The following are data on the consumption of the chlorinated hydrocarbon solvents in 1971.

Methyl Chloroform Consumption

		Millions of Pounds	Percent
Cleaning solvent		250	67%
Cold cleaning	200		
Vapor degreasing	50		
Exports		50	13
Vinylidene chloride		35	9
Miscellaneous		40	11
Total		375	100%

Trichloroethylene Consumption

	Millions of Pounds	Percent
Metal Cleaning	455	84
Exports	52	10
Miscellaneous	32	6
Total	539	100

Estimated Perchloroethylene Consumption

	Millions of Pounds	Percent
Textile Industry	435	58%
Exports	125	17
Metal Cleaning	110	15
Chemical Intermediate	70	9
Miscellaneous	8	1
Total	748	100%

Source: Chemical Economics Handbook

IV. CURRENT PRACTICE

Methyl chloroform is substantially stable under usual handling conditions, although it is sensitive to hydrolysis. The commercial product always contains small amounts of stabilizing substances, the most common of which are: glycol diesters, solvent ketone mixtures, nitriles, dialkyl sulfoxides, imines, dialkyl sulfides, dialkyl sulfites, tetraalkyllead, morpholine, nitroaliphatic hydrocarbons, 2-methyl-3-butyn-2-ol, tertiary butyl alcohol, tetrahydrofuran, 1,4-dioxane, sec-butyl alcohol, and monohydric acetylenic alcohols.

Stabilized methyl chloroform can be stored in mild steel tanks fitted with a drier to prevent ingress of moisture. It is transported in lacquer-lined mild steel drums (Kirk-Othmer, 1964).

Hill (1962) investigated the possibility of non-flammable halohydrocarbons forming explosive mixtures at elevated pressures. Methyl chloroform liquid at 24°C pressured to 6 lb/sq. in. gauge could not be ignited by fusing a one-inch nichrome wire at 50 or 80 volts. When the system temperature was raised to 36°C and the pressure to 26.5 lb/sq. in. gauge, and fired at 80 volts, a moderate temperature increase and a pressure surge to 65 lb/sq. in. gauge occurred.

The most exothermic combustion reaction which can be written for this compound is:

$CH_3CCl_3 + 2O_2 \rightarrow 2CO_2 + 3HCl$

H = -218 Kcal.

Experimental results indicate that this reaction probably did not occur. A more likely initial combustion reaction is:

$CH_3CCl_3 + 1.75\ O_2 \rightarrow CO_2 + 1.5\ H_2O + CCl_3^{\bullet}$

H = ca -33 Kcal.

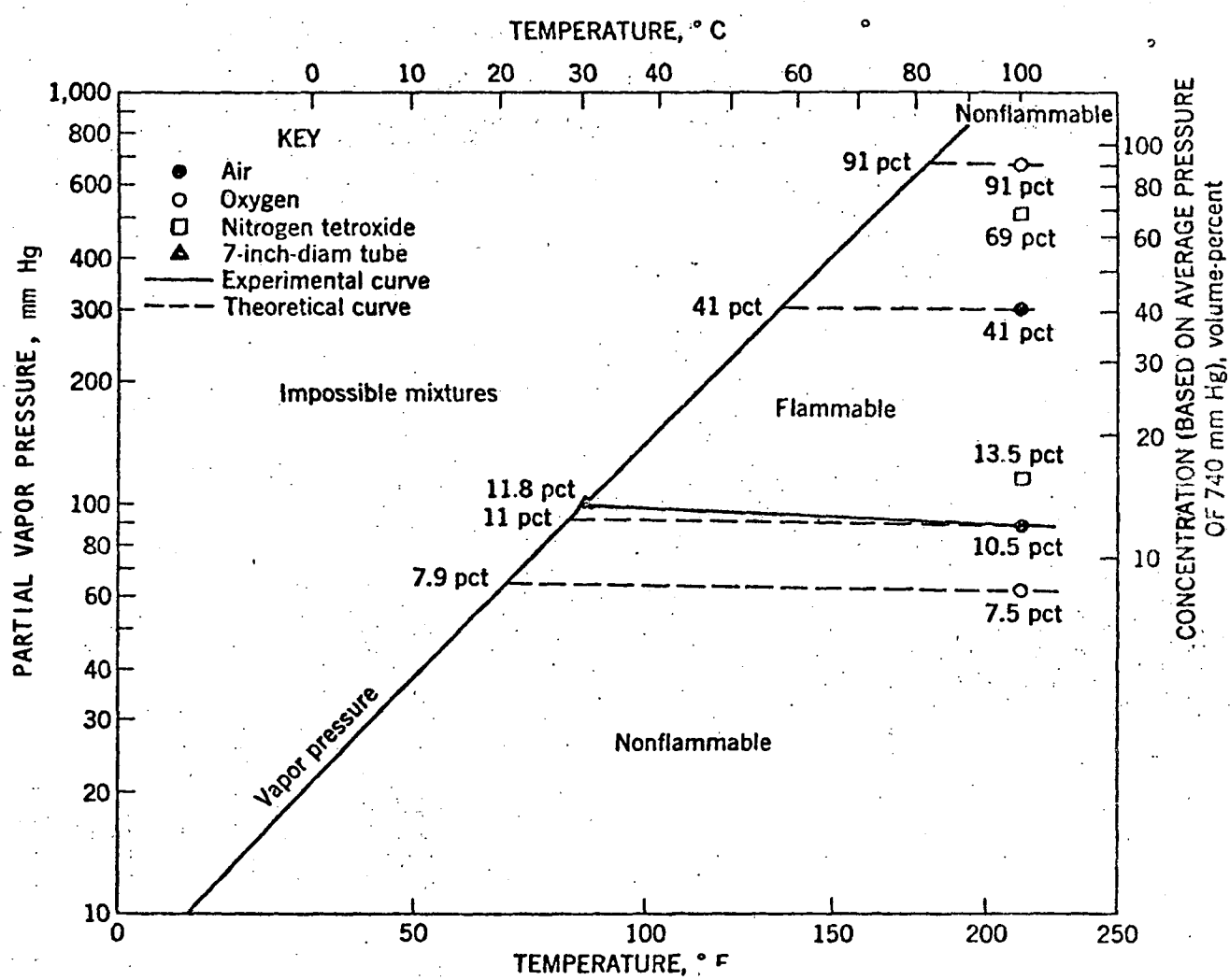
This mildly exothermic reaction would be followed by exothermic reaction of of the $CCl^{\bullet}$ radical such as:

$2\ CCl_3^{\bullet} \rightarrow C_2Cl_4 + Cl_2$

resulting in over-all heat release of about 75 Kcal. per mole of oxygen consumed.

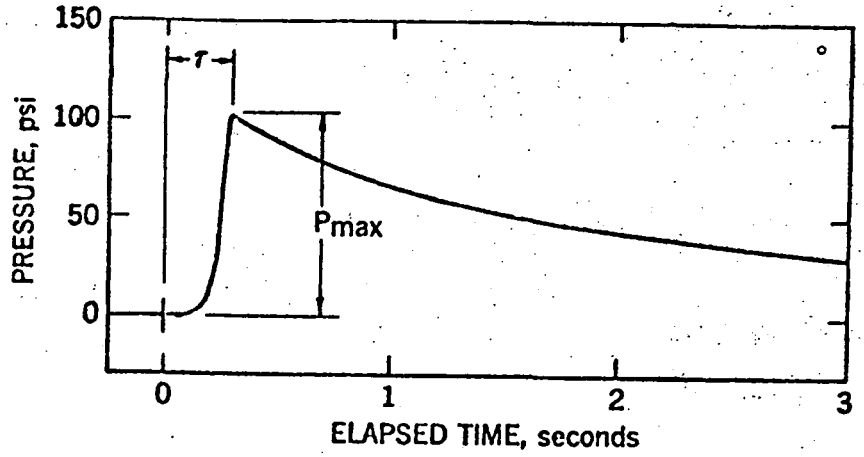
Methyl chloroform will burn, although not energetically, at a temperature of 36 C and a pressure of 26 lb/sq. in.

The flammability of trichloroethylene-air mixtures has been incorrectly assessed in the literature. Several reported explosions led to an investigation by the Bureau of Mines (Perlee, 1966) on the conditions under which such explosions can occur. The results of these investigations show that if trichloroethylene is handled in the manner prescribed in Chemical Safety Data Sheet No. 14, published by the Manufacturers and the Manufacturing Chemists' Association, fires and explosions need not be encountered. Pertinent data from these investigations are given here.



Temperature Dependence of Vapor Pressure of TCE and Concentration Limits of Flammability of TCE-Air, TCE-Oxygen, and TCE-Nitrogen Tetroxide Mixtures.

Source: PERLEE, 1966



Typical Pressure History Curve for Constant Volume Combustion of a 15 Volume-Percent TCE-Oxygen Mixture at About 29° C.

TABLE 2. - Maximum pressure and burning time for constant volume combustion of near limit mixtures of TCE-air and TCE-oxygen.

Mixture composition (volume percent)		P_{max} (psig)	τ (sec)
TCE	Oxidant		
13	Air	49	5.0
14	Air	50	5.2
15	Air	51	7.0
16	Oxygen	96	.9
15	Oxygen	138	.2
15	Oxygen	129	.3

Source: PERLEE, 1966

The United States Pharmacopeia (1970) states that trichloroethylene should be preserved in tight, light-resistant containers. It should be kept from prolonged exposure to excessive heat. The containers must bear the statements "Caution - repeated use may cause liver damage" and Warning - trichloroethylene must not be used in any closed-circuit rebreathing system utilizing soda lime or other alkali because phosgene or other toxic products may be formed."

The standard container of trichloroethylene is usually 300 ml. It is stored and shipped in lined tin or galvanized mild steel drums, fitted with screw caps or some other suitably tight method of closure. Lare quantities are shipped in road or rail tank cars. Large-scale storage tanks should be of mild steel, fitted with a dryer. Vents should, of course, lead to a safe point outside the storage building.

Commercial trichloroethylene stabilizers cover a tremendous variety of chemicals, some of which are: acetone, aniline, borate esters, epoxy compounds, hydroxyanisole derivatives, hydrazones, isocyanates, nitro compounds, phenol, pyrrolinic derivatives, stearates, tetrahydrofuran, and thiazoles.

The methods and conditions for the storage and transport of tetrachloroethylene closely follow those for trichloroethylene. Tetrachloroethylene, however, may also be stored in cast iron or galvanized iron containers.

V. ENVIRONMENTAL CONTAMINATION

Since the chlorinated hydrocarbons are employed chiefly as solvents, particularly in metal degreasing and dry-cleaning, their primary escape route into the atmosphere is by evaporation. A secondary source of contamination is the presence of these solvents in effluents. It has been estimated (Murray, 1973) that each year in the United States 2×10^5 tons of these chemicals are lost to the environment.

There are three mechanisms by which solvent vapors escape from a vapor degreasing plant: by external air currents, thermal convection currents, and molecular diffusion (Greve, 1971).

Synthetic fibers retain a certain amount of solvent, holding as much as 5% on the weight of the cloth. This solvent can volatize in a framing oven, or in a storage room or warehouse from which it passes to the outside atmosphere.

The efficiency of solvent recovery from a variety of sources has been claimed to be on the order of 95%, which leaves room for pollution problems in large-scale operations (Willard, 1972).

In the literature collected, surprisingly little information appeared on the incidence of methyl chloroform, trichloroethylene, and tetrachloroethylene in the air, in ground waters, or in surface waters. No information at all is available about the levels in the environment of the United States.

In an introductory study on samples of surface waters collected from the northeast Atlantic in August, 1972, an average of 7 ng per L of trichloroethylene and 9.5 ng per l of tetrachloroethylene were found. Molluscs from the relatively unpolluted water around the Isle of Man had accumulted significant concentrations of several chlorine compounds, none of which were specifically

named in the published report of the studied conducted.

In air samples taken from over the northeast Atlantic and from the rural areas of Britain, 6 ng m^{-3} of trichloroethylene and 5 ng m^{-3} of tetrachloroethylene were found (Murray, 1973).

VI. MONITORING AND ANALYSIS

Many of the classical analytical procedures which employ techniques such as combustion, hydrolysis, and the Beilstein reaction are still used, although these are nonspecific since they relate total chlorine to the desired component. They are therefore quantitative when a single compound is being tested, but are qualitative only, when a mixture is being tested.

The colors of the products obtained from the reaction of the chlorinated hydrocarbon solvents with pyridine and sodium hydroxide (Fujiwara reaction) are colorimetrically applicable. The reaction of tetrachloroethylene with pyridine aniline, and sodium methylate offers increased sensitivity and more stable color than the Fujiwara reaction. A comprehensive presentation of these analytical methods is included in The Encyclopedia of Industrial Chemical Analysis.

Gas chromatography, infrared spectroscopy, and mass spectroscopy can distinguish between individual compounds and give qualitative and quantitative data on those present.

A. Analysis of Mixtures

In the field sampling of air, Grupinski (1966) mentions the possibility of error through loss of the higher-boiling solvents by condensation in the gas sample container during transport. Drasche (1972) recommends Teflon bags to store exhaust gases from motor vehicles (excepting methane and acetylene) for several days duration. Initial volumes can be attained by heating the bags. Saran bags are recommended for long-term storage in the presence of carbon monoxide, methane, or acetylene in the air samples.

However, the use of charcoal tubes for collecting air samples prior to gas chromatography testing has been shown to be efficient and practical. The air to be sampled is aspirated through a standard charcoal sampling tube at an accurately measured rate of 1 to 2 liters per minute. The charcoal is trans-

ferred to a glass-stoppered Erlenmeyer flask, 3 ml of carbon disulfide is added, the flask is stoppered, allowed to stand for 10 min, and gently swirled. A 10 ml aliquot is injected into the gas chromatograph. This method gives average recovery values of 96%, 102%, and 100% for methyl chloroform; 88%, 96%, and 100% for trichloroethylene; and 92%, 95%, and 97% for perchloroethylene (Reid, 1968).

A rapid field sampling of halogenated hydrocarbons in crude oil is given by Jordan (1967). Description of the distillation apparatus is given together with the experimental details. Pyridine and NaOH are added to the distillate and read colorimetrically against standards prepared with kerosene. The lower detection limit of methyl chloroform is 90 ppm, with 1 ppm for trichloroethylene, and 500 ppm for tetrachloroethylene.

Methyl chloroform, trichloroethylene, and tetrachloroethylene can be determined in sewage sludge by either of two methods: 1) the solvents are isolated from the sample by steam distillation, dissolved in n-hexane or in cyclohexane, reduced with sodium, and the free chloride ions are determined titrimetrically; this method has a detection limit of 0.1 mg of chlorine per liter of sludge. 2) The solvents are dissolved in ethanol or cyclohexane, purified with Na_2SO_4, and analyzed by gas chromatography (Montgomery, 1967).

A rapid method for separating and identifying chlorinated solvents in paint was developed by Crippen and Emmerling (1960). The volatile solvents are separated from the paints either by conventional distillation or steam distillation. The condensate is injected into gas-phase chromatograph operating between 70-125°F, with a helium flow rate of approximately 75 ml/min in Perkin Elmer packed columns. The identity of the peaks is determined by time of emergence (retention time) of the peak under given to temperature, gas flow, and column

packing. If a peak is questionable, it may be trapped and examined on an infrared instrument for positive identity. These procedures are useful also in examining blood and body fluids for inhalation or absorption of chlorinated solvents.

Infrared spectrophotometric methods for determing trichloroethylene and tetrachloroethylene in various pharmaceuticals are described by Carol (1955) and Healton (1962).

B. Trichloroethylene

Campbell (1959) bubbled contaminated air through toluene at 1 L per min. to test the applicability to air of the method of Seto and Schultze (1956), which is a modified Fujiwara reaction developed for determining trichloroethylene in urine, This is a colorimetric prodedure in which the sample is mixed with toluene, followed by addition of pyridine and ethanolic potassium hydroxide. The results of this method used on air were comparable to the results obtained after dehalogenation with sodium biphenyl and subsequent determination of the chloride ion by the mercuric thiocyanate method.

Gage (1959) describes an air sampling system for trichloroethylene determination, consisting of two tubes connected in series. The first tube contains a layer of silica gel impregnated with potassium permanganate and orthophosphoric acid. The second tube contains silica gel impregnated with o-toluidine hydrochloride and serves to measure chlorine liberated by the first tube by the depth of color development. The life of these tubes is nine months and their precision is adequate for industrial hygiene air analysis.

Another application of active charcoal for the adsorption of chlorinated hydrocarbon solvents is demonstrated by Herbolsheimer (1972). In this case air

is sampled in work areas at the head level of workers. N-decane is used as the desorption reagent and the determination is carried out on a gas chromatograph with a dual flame ionization detector. In testing for trichloroethylene, this method gives reproducibility of 95-100% and is quantitative to 1 ppm.

To determine trichloroethylene residues in spice oleoresins after solvent extraction, Roberts (1968) used a microcoulometric gas chromatograph and read the results against reference standards.

Using activation analysis, Morgan and Duxbury (1965) developed a method for determing trichloroethylene in air. The air sample is drawn through a small charcoal pack by means of a battery-operated air flux and the Cl^{38} formed is determined by γ-spectrometry. The lower limit of detection on the equipment used was about 1 mg of chloride.

Versie, Dodinval-Versie, Heusghem, and Moreau (1962) used gas chromatography to determine the concentration of trichloroethylene in blood following intoxication. A 210 ml sample of blood was drawn from 345 of brain tissue. The sample was treated with distilled water and toluene, before being analyzed for trichloroethylene under the following conditions: Instrument, Perken Elmer vapor fractometer; stationary phase, 25% didecylphthalate on cellite 545; mobile phase, hydrogen; temperature, 83°C; voltage, 6.5V; flow rate 3.3 l/hr; pressure, 9.5 kg/cm^2; sensitivity, 1 part of trichloroethylene to 32 parts of toluene.

C. Tetrachloroethylene

The Hygienic Guide Series (1960) recommends that air to be tested for tetrachloroethylene should be collected on silica gel followed by hydrolysis with metallic sodium and determination of halide content. The alternatives

mentioned are expulsion from the silica gel by heat, followed by combustion, trapping the chloride in sodium carbonate-sodium formate solution and titrating the trapped chlorine, or a direct combustion method followed by chloride titration.

Strawberries which have been fumigated with tetrachloroethylene can be tested for residue nephelometrically after extracting the tetrachloroethylene with ethyl ether and evaporating in the presence of ethyl benzene (Mapes, 1954). Deshusses (1955) extracted the tetrachloroethylene from fruit by thermal deconposition and titrated the liberated HCl with $HgNO_3$.

VII. CHEMICAL REACTIVITY

Chlorinated solvents in vapor concentrations of a few ppm may decompose if they contact open flames and/or hot surfaces. The decomposition products are hydrogen chloride, carbon dioxide, carbon monoxide and phosgene.

A. Methyl Chloroform

Possessing no unsaturation, methyl chloroform is inert to atmospheric oxidation under normal handling conditions. It is, however, easily hydrolysed in an excess of free water, especially at elevated temperatures and in the gas phase (Dyhrenfurth, 1972).

Heated at 75-160°C with water under pressure, methyl chloroform decomposes in the presence of sulfuric acid or metal chlorides, according to the quantity of water present, to give acetyl chloride, acetic acid, or acetic anhydride. At temperatures over 370°C methyl chloroform is subject to atmospheric oxidation yielding phosgene as one of the decomposition products, with 1,1-dichloroethylene and HCl also given off.

In contact with iron at 402°C, copper at 369°C, zinc at 338°C, aluminum at 354°C, brass at 354°C, and steel at 354°C, the amounts of phosgene in the decomposition products are respectively, 0.8, 0.4, 1.9, 0.3, and 0.3 mg of phosgene per gm of methyl chloroform (Noweir, 1972).

Methyl chloroform reacts with chlorine in sunlight to give 1,1,1,2-tetrachloroethane, along with small quantities of penta- and hexachloroethane. Reaction with anhydrous hydrogen fluoride at 144°C in the absence of a catalyst results in formation of 1,1-dichloro-1-fluoroethane and 1-chloro-1,1-difluoroethane (Kirk-Othmer, 1964).

B. Trichloroethylene

The unsaturated bonding in trichloroethylene is sensitive to atmospheric oxidation in light. However, in the presence of suitable stabilizers, it is stable to air, moisture, light, and contact with common metals up to 130°C, where it becomes corrosive to metal.

Trichloroethylene is not hydrolysed by water under normal conditions (Dyhrenfurth, 1972). It reacts with alkaline hydroxides at 150°C to give glycolic acid. Strong alkalies react readily with trichloroethylene to form explosive chloroacetylenes. Sodium carbonate and aqueous ammonia do not react. In the presence of soda lime at 37°C, trichloroethylene decomposes readily to dichloroacetylene, which then oxidizes readily to phosgene and carbon monoxide.

Trichloroethylene does not react with cold inorganic acids but decomposes violently in hot nitric acid.

In the presence of catalysts such as finely divided aluminum, or on exposure to light, thermal decomposition occurs at 120°C (Smith, 1966). In contact

with iron at 450°C, copper at 500°C, zinc at 450°C and aluminum at 425°C, the amount of phosgene in the decomposition products is 19, 31, 69 and 35 mg of phosgene, respectively, per gm of trichloroethylene (Noweir, 1972).

When trichloroethylene is heated to 700°C, the vapor decomposes to give a mixture of dichloroethylene, perchloroethylene, carbon tetrachloride, chloroform, and methyl chloride (Kirk-Othmer).

C. Tetrachloroethylene

Unstabilized tetrachloroethylene in contact with water for long periods slowly decomposes to trichloroacetic acid and HCl. It is sensitive to atmospheric oxidation on exposure to light, going to trichloroacetyl chloride. Stabilized tetrachloroethylene is inert to air, water, light, and common metals to 140°C.

Strong inorganic acids will oxidize tetrachloroethylene to trichloroacetyl chloride and tetrachlorodinitroethane. With ozone, it is decomposed to phosgene and trichloroacetyl chloride (Kirk-Othmer).

In contact with iron at 450°C, zinc at 400°C, and aluminum at 400°C, the amount of phosgene given off in mg of phosgene per gm of tetrachloroethylene is 37, 17, and 3, respectively (Noweir, 1972).

VIII. BIOLOGY

A. ABSORPTION

Methyl chloroform, trichloroethylene, and tetrachloroethylene are volatile compounds and inhalation is the dominant intake route into human or animal systems. They are absorbed very rapidly through the lungs and gastrointestinal tract.

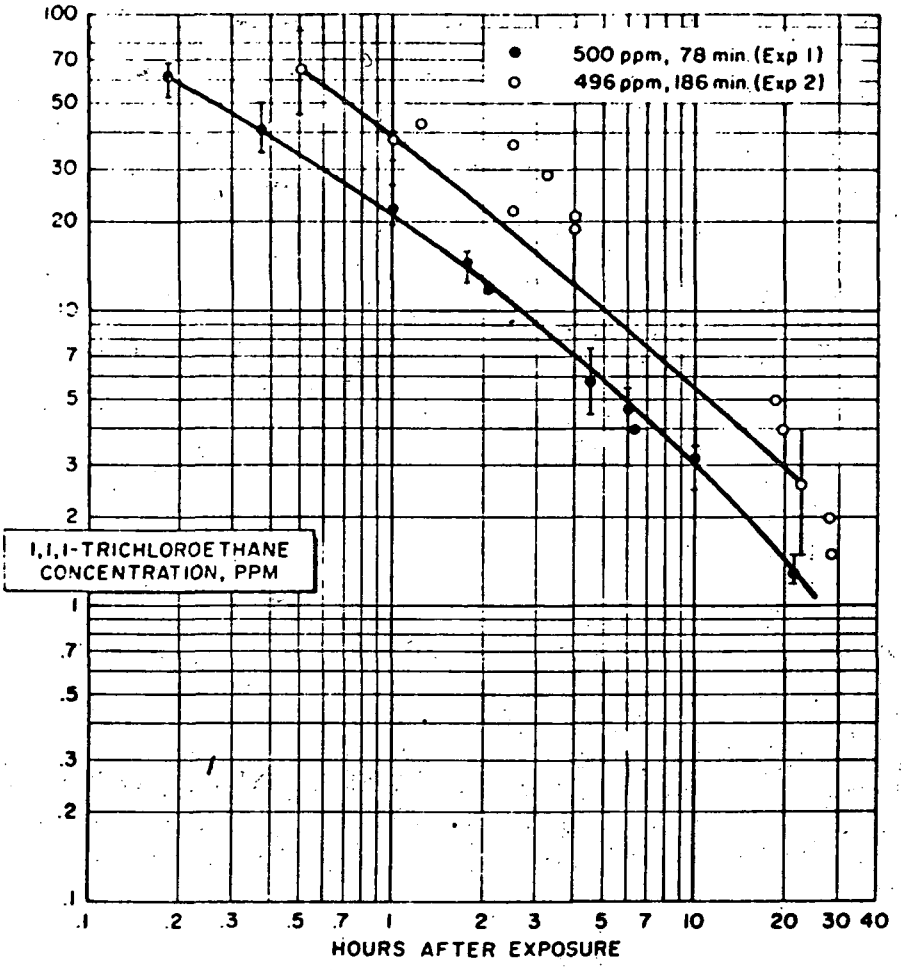
Skin absorption studies were performed on these three solvents using six human subjects. The skin of the hands was exposed to the solvents and the amount of the compounds in the alveolar air during the skin exposure and in the post-exposure period was determined by gas-chromatography. While all the solvents penetrated the skin, it was concluded that they would not be likely to be absorbed in toxic quantities when in contact with the skin of the hands and arms (Stewart and Dodd, 1964).

McBirney (1954) reports paralysis of the thumb and forefinger following intermittent repeated immersion of the hands in trichloroethylene under industrial conditions.

B. EXCRETION

1. Methyl chloroform

Studies involving the inhalation of methyl chloroform by human subjects shows that the excretion of unchanged methyl chloroform via expired air has an inverse exponential relationship to the time after exposure.



1,1,1-Trichloroethane Expired Air Concentration. Humans were exposed to atmospheric concentrations of 500 ppm for 78 minutes (Exp. 1) and 496 ppm for 186 minutes (Exp. 2).

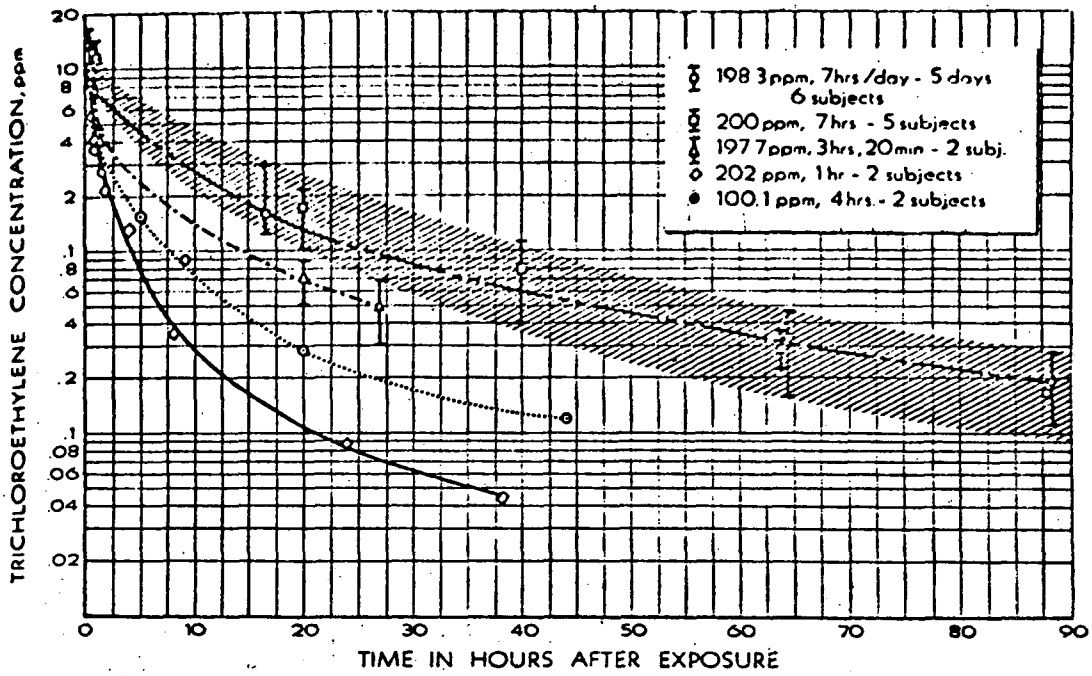
SOURCE: Stewart and Gay, 1961 (1)

Following absorption of methyl chloroform, most of the compound is excreted unchanged in the expired air and the metabolites trichloroethanol and trichloroacetic acid appear in the urine (Stewart, 1968).

The concentrations of methyl chloroform in human urine samples taken during exposure indicated that some samples possibly contained up to 2 ppm of the compound. Samples obtained 15 minutes after exposure revealed the presence of a trace amount in some, with none being detected in others (Stewart and Gay, 1961 (1)).

2. Trichloroethylene

The following data are given by Stewart and Dodd (1970), demonstrating the excretion of trichloroethylene in the expired air of human subjects after exposure.



Following exposure, concentration of trichloroethylene in the expired breath decreased exponentially. Concentration mean and range are plotted. Amount of solvent present related to both duration of exposure and concentration of solvent during exposure.

Bartonicek (1962) measured the excretion of trichloroethylene by 9 human volunteers who inhaled 1 g/m^3 of the compound for 5 hours. He found the retention rate to be 51-64%. The greatest amount of the trichloroethylene which was excreted via the lungs was exhaled on the 1st and 2nd days after exposure, and in traces on the third day. Of the trichloroethylene retained, 38 to 49.7% was excreted in the urine as trichloroethanol and 27.4 to 35.7% as trichloroacetic acid. 8.4% was excreted in the feces in the form of metabolites. The remainder was excreted in perspiration and in the saliva in the form of metabolites.

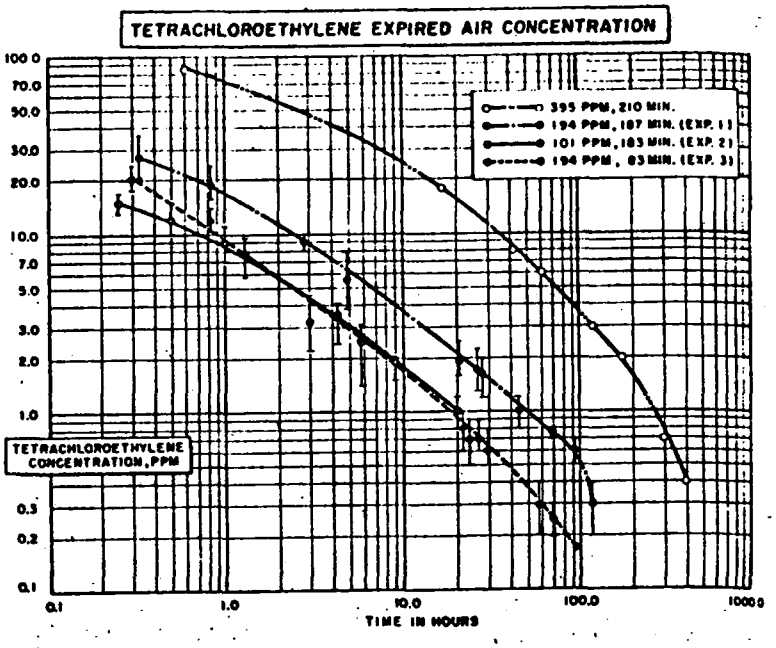
Ikeda (1972) calculated that only one-third of the trichloroethylene absorbed through the lungs was excreted in the urine during working time. His studies were performed on urine samples from 85 male workers from 17 workshops where the vapor concentration in the air was relatively constant.

In an earlier experiment, the excretion of trichloroethylene was investigated by Soucek (1959) using five human subjects. A 6% concentration of trichloroethylene was administered to the subjects by continuous inhalation for five hours. The subjects retained 630-1288 mg, representing 58-70% of the amount inhaled during exposure. Metabolites were present in the urine immediately after the beginning of inhalation. Excretion of these metabolites in the urine lasted between 312 to 520 hours.

3. Tetrachloroethylene

Mice were exposed for 2 hours to tetrachloroethylene-C^{14} vapor. In 4 days 70% of the amount inhaled was excreted in the expired air, and 20% appeared in the urine in the form of metabolites (Yllner, 1961).

Six human subjects were exposed to tetrachloroethylene vapor, 194 ppm for 187 minutes. No tetrachloroethylene was found in the urine. Following is a plot of the exhalation of the compound in time.



-Tetrachloroethylene expired air concentrations following vapor exposure. Mean concentration and range are plotted.

SOURCE: Stewart and Gay, 1961 (2)

C. TRANSPORT AND DISTRIBUTION

1. Methyl chloroform

Six subjects were exposed to methyl chloroform at 500 ppm for 78 minutes. Analysis of serial blood samples obtained during the exposure revealed that the average concentrations of methyl chloroform in the blood at 30, 60, and 75 minutes after the start of the exposure were all between 3 and 4 ppm (Stewart and Gay, 1961 (1)).

No studies on the distribution of methyl chloroform or its metabolites in the tissues are reported in the material at hand.

2. Trichloroethylene

Trichloroethylene tissue uptake after vapor exposure was investigated on dogs. Exposures were both acute and chronic with exposure times varying from 25 minutes to 219 hours at trichloroethylene concentrations ranging from 7,000 ppm to 20,000 ppm. After sacrificing the animals, cardiac blood and cerebral spinal fluid were removed for immediate extraction, and tissues were frozen until ready for processing.

The trichloroethylene concentration was determined colorimetrically after extraction from the various tissues. Known amounts of trichloroethylene were added to various tissues of normal animals as extraction controls.

TRICHLOROETHYLENE RECOVERED FROM TISSUE

(Corrected—in milligrams per cent wet weight)

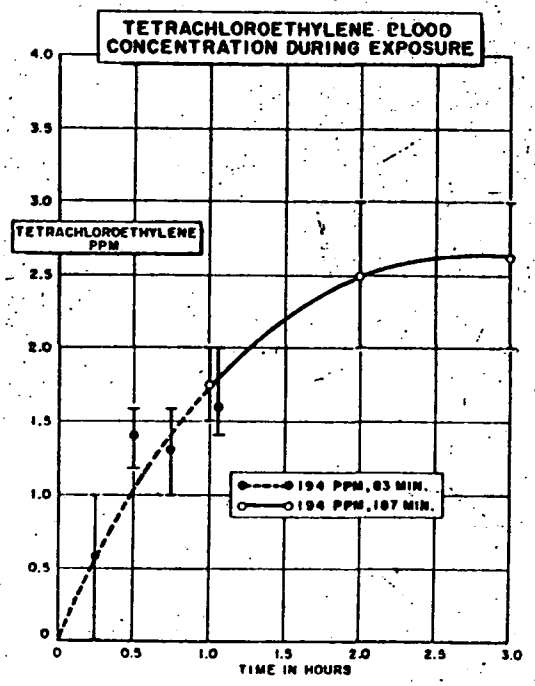
Animal Number	Mode of Exposure	Adrenal	Blood	Brain	Fat	Heart	Kidney	Liver
12	Acute	22.4	72.5	17.0	17.9	8.6	1.6	27.0
15	Acute	6.24	46.0	15.1	14.7	5.0	8.2	9.6
16	Acute	—	52.7	19.7	—	5.4	5.8	38.8
17	Acute	—	22.3	—	4.8	4.2	3.6	10.8
20	Acute	22.5	28.4	8.2	70.4	18.9	3.2	9.2
25	Acute ×3	13.8	50.0	20.9	70.5	13.9	17.5	49.4
14	Chronic-Acute	60.6	46.1	—	—	7.5	21.1	20.6
21	Chronic-Acute	23.1	50.6	23.6	22.1	12.9	5.3	9.7
19	Chronic	—	9.6	2.7	30.7	1.2	1.0	3.2
22	Chronic	0.94	0.13	0.22	14.4	0.11	0.13	0.12
24	Chronic	1.06	0.25	0.22	6.5	0.11	0.25	0.25

Animal Number	Mode of Exposure	Lung	Muscle	Pancreas	Spinal Cord	Cerebro Spinal Fluid	Spleen	Thyroid
12	Acute	2.8	2.7	—	8.8	—	0.71	—
15	Acute	2.2	—	3.2	—	3.8	3.9	2.0
16	Acute	0.92	0.15	9.8	—	1.5	1.2	6.6
17	Acute	0.92	3.3	6.4	—	0.61	5.4	—
20	Acute	0.40	5.1	14.1	—	1.7	1.3	3.9
25	Acute ×3	10.4	9.3	43.8	28.3	—	5.1	14.1
14	Chronic-Acute	2.0	—	8.1	—	0.15	—	5.8
21	Chronic-Acute	1.3	3.8	16.0	—	1.8	8.5	7.4
19	Chronic	0.53	4.1	2.5	—	0.15	0.71	1.1
22	Chronic	0.26	0.45	<0.05	0.13	0.15	<0.05	<0.05
24	Chronic	0.13	0.30	0.28	0.13	0.15	0.12	0.63

SOURCE: Cohen, 1958

3. Tetrachloroethylene

Human volunteers were subjected to exposures of tetrachloroethylene vapor and the following amounts of the compound were found in the blood:



SOURCE: Stewart and Gay, 1961 (2)

D. METABOLISM AND METABOLIC EFFECTS

Five male volunteers were exposed to 500 ppm of methyl chloroform, 7 hours per day for 5 consecutive days. Nine months later the same subjects were exposed to trichloroethylene vapor, 200 ppm, 7 hours per day for 5 days. Twenty-four hour urine collections obtained before, during, and following these vapor exposures were analyzed for trichloroethanol and trichloroacetic acid. Results were as follows:

URINARY EXCRETION OF TRICHLOROACETIC ACID (TAC) AND TRICHLOROETHANOL (TCE) IN FIVE SUBJECTS DURING AND FOLLOWING VAPOR EXPOSURES TO 1,1,1-TRICHLOROETHANE AND TRICHLOROETHYLENE

	1,1,1-Trichloroethane, 500 ppm 7 hr/day for 5 days		Trichloroethylene, 200 ppm 7 hr/day for 5 days	
	TCA (mg/24 hr)	TCE (mg/24 hr)	TCA (mg/24 hr)	TCE (mg/24 hr)
Control value (mean and range)	14,2 (8–22,8)	< 1 (<1–1)	2 (1–4)	<1 (<1–3)
1st Exposure day	7,5 (2,6–10,5)	20,1 (7,9–49)	51 (34–84)	308 (179–430)
2nd Exposure day	10,9 (8,2–19,3)	30,1 (14,8–66,5	175 (113–238)	359 (294–480)
3rd Exposure day	12,3 (5,6–27)	29,3 (19,1–51)	229 (148–416)	399 (296–546)
4th Exposure day	14,1 (7,8–19,2)	46,6 (23,4–93,6)	306 (231–439)	538 (249–822)
5th Day following last exposure	18 (13–26)	7 (1–14,9)	50 (35–61)	15 (10–18)
12th Day following last exposure	17,5 (8–22)	<1 (<1,)	8 (2–22)	14 (1–37)

SOURCE: Stewart, 1968

Ikeda (1972) obtained the following results from the urine of workers who had been exposed to trichloroethylene:

Trichloroethylene (p.p.m.)	*Workshop for*	*No. of workers*	*Metabolite concentration*[2]				
			TTC[3]	*TCE*[3]	*TCA*[3]	*TTC (1·016)*[4]	*TTC (creatinine)*[5]
0	–	36[a]	<1	0[3]	<1		
3	I	9	39·4 (26·5– 58·7)	25·1 (14·2– 44·6)	12·7 (8·8– 18·2)	35·4 (26·7– 47·0)	40·8 (30·3– 55·0)
5	II	5	45·6 (26·4– 78·9)	24·9 (16·3– 37·9)	20·2 (10·0– 40·8)	31·8 (17·8– 56·6)	42·4 (23·4– 76·7)
10	III	6	60·5 (37·6– 97·5)	42·0 (25·1– 70·3)	17·6 (10·3– 30·0)	41·1 (27·9– 60·4)	47·3 (24·5– 91·5)
25	II	4	164·3 (136·8– 197·3)	77·3 (52·3– 114·1)	77·2 (51·6–115·6)	101·7 (88·7– 116·6)	122·9 (87·4– 172·9)
40	II	4	324·9 (232·1– 454·8)	220·3 (164·4– 295·3)	90·6 (50·2–163·8)	204·4 (156·8– 266·3)	221·2 (155·5– 314·5)
45	II	5	399·0 (287·6– 553·5)	256·7 (202·1– 330·8)	138·4 (83·2–216·5)	253·3 (194·8– 329·5)	337·7 (267·8– 425·7)
50	IV	5	418·9 (228·4– 768·2)	267·3 (140·0– 510·3)	146·6 (76·3–281·7)	257·8 (154·6– 429·8)	275·8 (195·0– 390·3)
60	II	5	468·0 (347·9– 629·6)	307·9 (223·0– 425·6)	155·4 (104·3–231·4)	308·9 (228·8– 417·1)	359·0 (223·7– 576·1)
120	V	4	915·3 (775·7–1079·9)	681·8 (581·4– 799·5)	230·1 (199·0–267·4)	481·1 (414·6– 558·3)	518·9 (354·3– 759·7)
175	V	4	1210·9 (790·7–1854·2)	973·1 (596·9–1586·4)	235·8 (187·2–296·9)	939·1 (770·6–1144·3)	1040·1 (711·3–1520·9)

Types of workshops: I, synthesis of trichloroethylene; II, continuous automatic degreasing of metal parts, wire, or steel plates; III, cellophane printing; IV, coating with glue; V, development of photo-printed electronic circuit.

[a]Exposed daily, 8 hours a day, 6 days a week.

[2]Geometric means together with SD ranges in parentheses.

[3]TTC, TCE and TCA stand for measured values (mg/litre) of total trichloro-compounds, trichloroethanol and trichloroacetic acid, respectively.

[4]Total trichloro-compounds concentration (mg/litre) adjusted to a specific gravity of urine of 1·016.

[5]Total trichloro-compounds concentration divided by creatinine concentration (mg/g creatinine).

Soucek (1960) determined that the amount of trichloroethylene retained by human subjects after inhalation was excreted in the urine as monochloroacetic acid, trichloroacetic acid, and trichloroethanol in the ratio 1:5:12. Mono-

chloroacetic acid appeared in the urine a few minutes after the beginning of the inhalation of the trichloroethylene vapor. The total quantity excreted represented an average of 4% of the quantity of trichloroethylene retained. Trichloroacetic acid appeared in the urine immediately after the beginning of the exposure. The average of the quantities excreted represents 19% of the retained trichloroethylene. Trichloroethanol appeared in the urine very soon after the start of the exposure, and its excretion corresponded to 50% of the retained trichloroethylene. In the various subjects the excretion of monochloroacetic acid continued for 48 to 168 hours, the excretion of trichloroacetic acid continued for 312 to 520 hours, and the excretion of trichloroethanol continued for 312 to 390 hours. The amount of trichloroethylene which was retained during the exposure was calculated to be between 58% and 70% of the amount inhaled.

Bartonicek (1962) determined a retention rate for trichloroethylene to be 51% to 64% of the amount inhaled by nine human subjects. An average of 45.4% of the amount retained was excreted as trichloroethanol and 31.9% as trichloroacetic acid.

The comparison of trichloroacetic acid plus the trichloroethanol in the urine and the feces (urine average 21.5 mg/100 ml; feces average 17.8 mg/100 ml) demonstrates that both metabolites pass into the digestive system through bile and saliva, and are secreted by liver cells and the salivary gland cells in amounts approximating those found in the urine.

Excretion of trichloroethanol and trichloroacetic acid in sweat demonstrates that trichloroethanol-glucuronide circulating in blood and trichloroacetic acid present in blood in ion form can pass into the parenchyma of sweat glands, and are not confined to the extracellular fluid.

Mikiskova (1966) reports that the known trichloroethylene metabolites possess their own physiological effects. Trichloroethanol is a central nervous system depressant, even when it is conjugated with glucuronic acid. Monochloroacetic

acid has choleretic and laxative action and is hepatotoxic at high doses. The toxicity of trichloroacetic acid is low.

The effect of trichloroethylene on tryptophan metabolism was studied by determining the 5-hydroxyindole content in the urine of exposed human and animal subjects (Corsi, 1963). A reduction of 5-hydroxyindole in the urine was determined after administration of trichloroethylene.

Little is reported on the metabolism of tetrachloroethylene. Yllner (1961) submitted mice to tetrachloroethylene-C^{14} vapor inhalation and detected the urinary metabolites: 52% trichloroacetic acid, 11% oxalic acid and traces of dichloroacetic acid. An epoxide is postulated as a metabolic intermediate, with further rearrangement to trichloroacetyl chloride and then to trichloroacetic acid.

Dmitrieva (1967) investigated the metabolism of tetrachloroethylene in rats and found ethylene glycol to be the dominant metabolite which was excreted in the urine. Trichloroacetic acid and oxalic acid were also determined.

It is surprising that no follow-up work was found in the literature concerning the presence of the ethylene glycol and oxalic acid in rat urine following exposure to tetrachloroethylene. Since it is not justifiable to apply to man the results from experiments on animals, it would be of prime concern here to establish that ethylene glycol and oxalic acid actually are metabolites of tetrachloroethylene in the rat, and to establish whether any specific analysis for these compound has been run on human urine following exposure to tetrachloroethylene.

When taken internally, ethylene glycol is extremely toxic. In fatal cases death has been due to renal failure, with crystals of oxalic acid deposited in the renal tubules. In poisoning by any of the glycols or their derivatives, the outstanding toxic effect is exerted on the kidneys (Browning, 1961).

In studies of tetrachloroethylene metabolism in humans, Haag (1958) reports trichloroacetic acid in the urine of two workers who had been exposed to tetrachloroethylene. Ikeda (1972) discusses the quantitative relationship between exposure to tetrachloroethylene and the concentration of the metabolites trichloroethanol and trichloroacetic acid.

IX. ENVIRONMENTAL TRANSPORT AND FATE

A. PERSISTENCE AND/OR DEGRADATION

There are many reports in the literature describing analytical methods for determining the concentrations of the chlorinated hydrocarbon solvents in air, but very little is published giving figures obtained during actual field tests or in monitoring the environment in the vicinity of industries in which these solvents are used.

Nothing was found in the literature concerning the persistence or degradation of the solvents under natural atmospheric conditions.

B. ENVIRONMENTAL TRANSPORT

The volatility of the chlorinated hydrocarbon solvents would provide the mechanism for their transport in air. Water transport would also distribute the solvents in the environment if they should escape in effluents from the cites where they are being used. Their specific gravity would tend to maximize effects in the bottoms of water streams or bodies.

C. BIOACCUMULATION

Murray (1973) reports on a preliminary investigation which showed that molluscs from the relatively unpolluted waters around Port Erin, Isle of Man, contain significant concentrations of several organic chlorine compounds in their tissues. Specific compounds found in these molluscs are not named in this paper and amounts of chlorine compounds detected are not given.

X. TOXICITY

A. HUMAN TOXICITY

1. Inhalation of Methyl Chloroform

The principle toxic action of a single vapor exposure of methyl chloroform is a functional depression of the central nervous system, proportional to the magnitude of exposure, and typical of an anesthetic agent (Stewart, 1968). Humans exposed to 900-1000 ppm experienced transient, mild eye irritation, light-headedness, and impairment of coordination. At a peak of 2650 ppm two of the subjects were unable to stand (Stewart, 1961 (1)). Below the current threshold limit value of 350 ppm no physiological effects have been observed.

Exposure time (min)	Concentration in air (ppm)	Expected effect in humans
60	100	Apparent odor threshold
	500	No detectable effect, but odor is obvious
	1000	Very slight loss of equilibrium
	2000	Loss of coordination
30	1000	Eye & nasal discomfort, slight loss of equilibrium
	2000	Loss of equilibrium
15	1000	Beginning of loss of equilibrium
5	2000	Disturbance of equilibrium

Source: Stewart, 1968

Investigating liver and kidney damage suffered by humans after exposure to methyl chloroform, Stewart, Gay, Erley, Hake, and Schaffer (1961 (1)) reported the following results:

1,1,1-Trichloroethane Pre- and Postexposure Data

	Subject	SGO-T			Urinary Urobilinogen				Urinalysis				15 min. P.S.P.	
		Preexposure	20 hr. Post	7 da. Post	Preexposure	6 hr. Post	20 hr. Post	7 da. Post	Preexposure		20 hr. Postexposure		Preexposure	20 hr. Post-exposure
									Alb.	Micro.	Alb.	Micro		
Normal Value		6–40			1:40 or less				0–6 RBC/HPF				Greater than 25%	
Experiment 1	1	22	10	12	1:10		1:10	1:10	neg	neg	neg	neg		
500 ppm, 78 min.	4	14	14	10	1:10		1:10	1:10	neg	neg	neg	rare RBC		
	5	15	9	16	1:10		1:10	1:10	neg	rare RBC	trace	3–6 RBC		
	6	16	10	12	1:10		1:10	1:10	neg	1–2 RBC	neg	rare RBC		
	8	16	16	14	1:10		1:10	1:10	neg	rare RBC	neg	rare RBC		
	11	12	16	14	1:10		1:10	1:10	neg	neg	neg	neg		
Experiment 2	1	20	20	14	1:10		1:10	1:10					39%	44%
496 ppm, 186 min.	2	20	18	16	1:10		1:10	1:10					38%	31.5%
	5	16	16	10	1:10		1:10	1:10					40%	39%
	6	23	20	18	1:10		1:10	1:10					43%	44%
	8	20	18	19	1:10		1:10						29%	24%
	10	24	19		1:10		1:10							
Experiment 3	5	16	18	16	1:10		1:10	1:10	neg	0–2 RBC	neg	rare RBC		
955 ppm, 73 min.	6	19	16	12	1:10		1:10	1:10	neg	neg	neg	neg		
	8	18	16	15	1:10		1:10	1:10	neg	neg	neg	neg		
Experiment 4	3	14	16	6	1:10		1:10	1:10	neg	rare RBC	neg	rare RBC		
910 ppm, 35 min.	4	18	18	16	1:10		1:10	1:10	neg	neg	neg	neg		
Experiment 5	2	17	15	14	1:10		1:10	1:10	neg	rare RBC	neg	neg		
900 ppm, 20 min.	7	18	20	17	1:10		1:10	1:10	neg	neg	neg	neg		
	9	16	18	20	1:10		1:10	1:10	neg	neg	neg	neg		
Experiment 6	1	14	16	15	1:10	1:640	1:10	1:40	neg	neg	neg	neg		
0–2650 ppm, 15	2	16	15	15	1:10		1:10	1:10	neg	neg	neg	neg		
min.	3	10	11	16	1:10	1:640	1:10	1:10	neg	neg	neg	rare RBC		
	4	14	14	18	1:10	1:10	1:10	1:10	neg	neg	neg	rare RBC		
	5	14		14	1:10		1:10	1:10	neg	neg				
	6	15	15	19	1:10		1:10	1:10	neg	neg	neg	0–2 RBC		
	7	14	16	20	1:10	1:40	1:10	1:20	neg	neg	neg	1–5 RBC		

These data show that methyl chloroform has the capacity to exert adverse effects on the liver and kidneys. Although in Experiment 6, it might seem that the liver dysfunction is transient, subject 1 and subject 7 exhibited increased urinary urobilinogen values on the seventh day following the exposure. This would indicate the possibility of liver damage in predisposed individuals who would be subjected to a chronic exposure to methyl chloroform. While the serum glutamic oxaloacetic transaminase (SGO-T) values and the 15-minute phenolsulfonphalein

excretion values following exposure deviated somewhat from the preexposure values, they remained within normal limits.

Death results from the absorption of a toxic quantity of methyl chloroform, following functional depression of the central nervous system with respiratory arrest, peripheral vascular collapse, or aspiration pneumonitis. The deaths from these causes are reported to have occurred in unventilated tanks where the concentration of methyl chloroform was well in excess of 5000 ppm.

Severe hypotension may be induced by a combination of central nervous system depression and myocardial anoxia, secondary to poor oxygen uptake.

However, no injury to man following repeated exposures to vapor concentrations of less than 500 ppm has been observed (Stewart, 1968).

2. Ingestion of Methyl Chloroform

Methyl chloroform is rapidly absorbed from the gastrointestinal tract and is rapidly excreted, unchanged, via the lungs. However, the ingestion of a toxic amount produces the same central nervous system sequel as does the inhalation of a toxic amount. If the amount ingested is sufficient to produce loss of consciousness, liver dysfunction may result.

One case of accidental ingestion of methyl chloroform has been reported (Stewart, 1968). Thirty minutes after a man ingested one ounce of this solvent, he became nauseated. One hour after ingestion, he experienced vomiting and diarrhea; this continued for two and one-half hours at which time the man became incapacitated. Laboratory studies at this time showed a leucocytosis and proteinuria. A slight eleva-

tion in the serum bilirubin level was noted forty-eight hours after ingestion. Six months following the ingestion, no deviation from the normal was noted in complete blood cell counts, urinalyses, serum glutamic oxaloacetic transaminase, serum glutamic pyruvic transaminase, blood urea nitrogen and electrocardiograms.

The median lethal oral dose of methyl chloroform in four species of experimental animals is reported to range from 8.6 to 14.3 gm/kg.

3. Skin Contact with Methyl Chloroform

Prolonged or repeated contact with the skin results in transient erythema and slight irritation. Several drops of this solvent splashed directly on the cornea may produce a mild conjunctivitis which subsides within a few days (Stewart, 1968).

4. Behavioral Effects of Methyl Chloroform

The daily exposure of humans to gaseous methyl chloroform (350 ppm or 450 ppm) did not impair performance in psychophysiological tests. The subjects were tested for perception, memory, reaction time, and dexterity.

Although there were some deviations from normal patterns, these were either not statistically significant or could be attributed to fatigue and mental strain (Salvini, 1971).

5. Inhalation of Trichloroethylene

Trichloroethylene is classified among the most toxic solvents. The acute toxicity of trichloroethylene with its predominant effects on the central nervous system was recognized during the First World War when it was substituted into degreasing systems. Individual cases of liver damage among industrial workers have been reported.

At trichloroethylene vapor concentrations of 150-250 ppm, workmen experienced neurologic symptoms, headaches, and fatigue. Hypoalbuminemia and hyperglobulinemia were observed in workers exposed for 5-10 months. When vapor concentrations were 50-100 ppm, the frequency of symptoms was reduced (Takamatso, 1962). The maximum permissible level for trichloroethylene in air was set at 100 ppm in the United States in 1961.

Ten experimental human exposures to trichloroethylene at a 200 ppm level were carried out for five consecutive days. During the exposure individual subjects complained of lightheadedness, headache, throat irritation, and mild eye irritation. Fatigue and drowsiness were experienced. All neurological tests were normal during exposure, but 50% of the subjects stated that greater mental effort was required to perform a modified Romberg test. With the exception of the 24-hour urine samples which contained solvent metabolites, none of the clinical laboratory tests performed during or following the vapor exposures were abnormal. Thus, there was no laboratory evidence that even transient organ dysfunction had occurred. Urinary urobilinogen tests, a most sensitive index of hepatic dysfunction, were normal (Stewart, 1970).

If excessive concentrations of trichloroethylene are inhaled over extended periods of time, varying degrees of poisoning may result. Workmen may become addicted to it. Deaths from acute exposures to trichloroethylene vapors most frequently result from narcosis to the point of respiratory arrest or from primary cardiac failure. Entry into a degreaser with trichloroethylene present was the most important single cause of serious injury or death (Morrill, 1963).

Longley (1963) states that acute unconsciousness can result from the inhalation of trichloroethylene in a concentration of 3000 ppm if the subject has had an immediately earlier exposure resulting in a mild intoxication. The generally accepted level of trichloroethylene required to cause unconsciousness is 10,000 ppm.

Capellini and Grisler (1958) studied the liver function in a group of twelve women who had worked in contact with trichloroethylene for at least two years. About one-half of the cases showed dyspeptic syndromes, liver enlargement, and serum protein changes. All cases had a slight hyperbilirubinemia. Serum total proteins, albumin, total and esterified cholesterol, alkaline phosphatase, blood glucose, and urea were within normal values.

A fatal addiction to trichloroethylene was reported by James (1963). A worker who showed evidence of addiction to the inhalation of trichloroethylene vapors developed paresis of the olfactory nerves with intermittant gastric disturbances over a nine-year period. Sudden death occurred seventeen hours after the last known exposure. On autopsy, fatty degeneration of the liver, and lung hemmorhage were found. The concentrations of trichloroethylene in the body were: 2.25 mg/100 ml in the blood, 7.1 mg in the liver, 19.9 mg in the stomach and its contents, and 14.9 mg in the small intestine and its contents. The urine contained 55.5 mg of trichloroacetic acid per 100 ml of urine.

In another addiction problem, Baerg and Kimberg (1970) found centrilobular hepatic necrosis and acute renal failure in trichloroethylene "sniffers". Three cases were involved. All had been inhaling fumes from cleaning fluid. The first patient was admitted to the hos-

pital with icterus. Tests of hepatic function were abnormal, but rapidly returned to normal. Biopsy of the liver revealed acute toxic centrilobular necrosis superimposed upon a previous centrilobular injury. The patient had an uneventful recovery and was discharged from the hospital on the thirteenth day after admission.

A second patient, who had also inhaled fumes from cleaning fluid was admitted to the hospital because of anuria of three-days' duration. The patient had acute tubular necrosis and toxic hepatitis, both secondary to trichloroethylene inhalation.

6. Ingestion of Trichloroethylene

General anesthesia was the outstanding feature in the clinical course of a human who ingested approximately 50 ml of trichloroethylene (Fleischhacker, 1956).

Stentiford and Logan (1956) report that an adult male who swallowed approximately 130 ml of trichloroethylene was comitose for two days. The foremost toxic sumptoms were short intermittent periods of very rapid heart action. The electrocardiogram showed prolongation of the P-R interval to 0.26 seconds. Liver function tests showed no abnormality. The urine contained no protein at any time during the course of recovery. There was no clinical evidence of residual damage to the cranial nerves. Full recovery ensued.

Meyer (1965) reviewed fifteen cases of peroral trichloroethylene intoxication, eight of which were fatal. All cases displayed central nervous system disturbances with cerebral edema, central respiratory paralysis, and psychosis. The electrocardiograms showed a pseudoinfarct and cardiac arrythmia. The blood pictures showed a shift to the left,

with anisocytosis, hypochromasia, polychromasia, and basophilic stippling. Kidney function disturbances were reversible. Toxic liver damage was not detected although degenerative changes were observed.

7. Skin Contact with Trichloroethylene

Although trichloroethylene is not absorbed through the intact skin in toxic amounts, heavy industrial exposures to this solvent have produced generalized dermatitis. Paralysis of the thumb and forefinger occurred in cases involving intermittent, repeated immersion of hands in the liquid. This disability lasted for several months after cessation of contact. There was no skin damage in any of the cases (McBirney, 1954).

8. Behavioral Effects of Trichloroethylene

Stopps and McLaughlin (1967) used manual dexterity tests (Crawford Small Parts Dexterity Test), card sorting, and dial display in measuring changes in psychophysiological function in human subjects exposed to trichloroethylene vapors. Four concentrations of trichloroethylene vapor were selected for the exposures: 100 ppm, 200 ppm, 300 ppm, and 400 ppm. Trichloroethylene showed no significant effect on psychomotor performance at the 100 ppm level. There is a slight decline in performance at the 200 ppm level, which becomes progressively more pronounced at the 300 ppm and 500 ppm concentrations.

Salvini, Binaschi, and Riva (1971) conducted studies similar to those immediately above, and reached similar conclusions. In these studies, the following tests were performed: perception test with tachistoscopic presentation, Wechsler Memory Scale, complex reaction time test, and manual dexterity test. In all the tests performed, a statistically

significant decrease in performance ability was seen with increasing vapor concentration inhaled. These workers concluded that 100 ppm of trichloroethylene is very close to the concentration capable of interfering with psychophysiological efficiency.

9. Inhalation of Tetrachloroethylene

Tetrachloroethylene is rapidly absorbed through the lungs and gastrointestinal tract and is rapidly excreted, unchanged, via the lungs. The primary toxic effect of a single vapor exposure is a functional depression of the central nervous system, proportional to the magnitude of exposure, and typical of an anesthetic agent. The early symptoms of acute overexposure (between 200 and 300 ppm) are light-headedness, and mild eye, nose, and throat irritation. Below the current threshold limit value of 100 ppm, no adverse physiological effects have been observed in man (Stewart, 1969).

Exposure time (min)	Concentration in air (ppm)	Response
1-4	75-80	Very slight eye irritation
4-6	100-120	Soft palate irritation and dryness
6-30	200	Odor not unpleasant
30+	210-244	Light-headedness

Following are laboratory studies performed on human subjects after experimental exposures to tetrachloroethylene:

LABORATORY STUDIES ON HUMAN SUBJECTS
AFTER TETRACHLOROETHYLENE EXPOSURE

		SGO-T			SGP-T			Urinary Urobilinogen			
Normal Value	Subject	Pre-exposure 6-40	20 Hr. Post	7 Day Post	Pre-exposure 6-30	20 Hr. Post	7 Day Post	Pre-exposure 1:40 or Less	6 Hr. Post	20 Hr. Post	7 Day Post
Exp. 1	1	12	18	18				1:10		1:10	1:10
194 ppm,	2	18	20	14				1:10		1:10	1:10
187 min.	3	16	18	18				1:10		1:10	1:10
	4	15	23	--				1:10		1:10	--
	5	15	15	14				1:10		1:10	1:10
	6	10	13	12				1:10		1:10	1:10
Exp. 2	2	16	16	18				1:10	1:10	1:10	1:10
194 ppm,	3	12	14	12				1:10	1:10	1:10	1:10
83 min.	6	6	10	12				1:10	1:10	1:10	1:10
	7	16	17	15				1:20	1:80	1:10	1:10
	8	17	19	20				1:160	1:320	1:10	1:10
	9	18	15	18				1:10	--	1:10	1:10
Exp. 3	1	16	12	14	16	14	14	1:10		1:10	1:10
101 ppm,	2	14	16	14	13	16	14	1:10		1:10	1:10
183 min.	3	16	14	13	17	16	16	1:10		1:10	1:10
	4	14	10	18	20	14	18	1:10		1:10	1:10
	5	16	12	16	16	12	14	1:10		1:10	1:10
	7	16	14	17	17	12	20	1:10		1:10	1:10

Source: Stewart, R. D., Gay, H. H., Erley, D. S., Hake, C. L., and Schaffer, A. W., 1961 (2).

Tetrachloroethylene does not possess great potential for causing serious liver or kidney injury, but repeated vapor exposures to high concentrations have produced hepatitis in experimental animals.

Acute renal failure, occasionally observed in man, is probably a consequence of the shock produced by the peripheral vascular collapse secondary to central nervous system depression.

The SGO-T and SGP-T (serum glutamic oxaloacetic transaminase and serum glutamic pyruvate transaminase) concentrations are useful indices of induced hepatocellular injury. In most cases, the degree and duration of elevation are related to the extent of liver damage.

Following are the results of laboratory studies on a man who had been overcome with tetrachloroethylene while cleaning a tank with this solvent. This patient experienced marked central nervous system depression, followed by transient, minimal liver damage.

Time After Exposure	SGOT, Units	SGPT, Units	24-hr Urinary Urobilinogen, Ehrlich Units	Total Serum Protein, gm/100 ml	Serum Albumin, %	Serum Bilirubin Total/Direct, mg/100 ml	Alkaline Phosphatase, King-Armstrong Units	BUN, mg/100 ml	Urinalysis	WBC/cu mm	Hematocrit, %	Reticulocyte Count, %
1½ hr	12	10	...	...	...	...	...	...	Specific gravity 1.015; no albumin; microscopically normal	10,200	45	...
2 days	41	10	2.4	7.1	64	0.4/0.2	11.4	...	No albumin; microscopically normal	8,700	46	...
3 days	31	10	2.6	6.9	62	0.4/0.2	11.4	...	No albumin; microscopically normal	11,400	45	0.7
5 days	14	10	2.1	6.4	69	0.4/0.1	10	12	No albumin; microscopically normal	10,200	44	0.3
9 days	14	10	7.2	...	...	...	13	...	No albumin; microscopically normal	11,900	44	0.5
10 days	...	...	...	6.5	69	0.4/0.1	11.4	...	...	9,800	46	0.4

Source: Stewart, 1969

Patel, Janakiram, Johnson, and Elman (1973) described a case of exposure to tetrachloroethylene in which acute pulmonary edema was the predominant symptom. The patient was admitted to the hospital in a

deep coma; the pulse rate was 88 beats per minute; the blood pressure was 88/20 mm Hg; the temperature was 34.4°C (94°F); and respirations were 48 per minute. Bubbling rales were heard over the entire lung fields.

After four days of treatment, the patient was well enough to leave the hospital. Tests of liver and kidney function, done during the four-day hospital stay and biweekly for several weeks afterwards, gave normal results.

Fatal poisoning by chronic inhalation of tetrachloroethylene vapor was reported by Transe and Zimmerman (1969). The symptoms of pulmonary disease which the patient initially manifested were diagnosed as miliary tuberculosis. Later, jaundice and oliguria appeared and the patient died nine days after the onset.

On autopsy, the lungs showed fibrin-rich exudate and intraparenchymal hemorrhage. The liver, large and greenish, showed extensive acute to subacute centrilobular necrosis. The heart showed fatty degeneration.

10. Ingestion of Tetrachloroethylene

No reports on human ingestion of tetrachloroethylene were found in the literature.

11. Skin Contact with Tetrachloroethylene

This solvent is poorly absorbed through the intact skin (Stewart, 1969).

12. Behavioral Effects of Tetrachloroethylene

Stewart, Baretta, Dodd, and Torkelson (1970) report an abnormal modified Romberg test in three subjects within the first three hours of

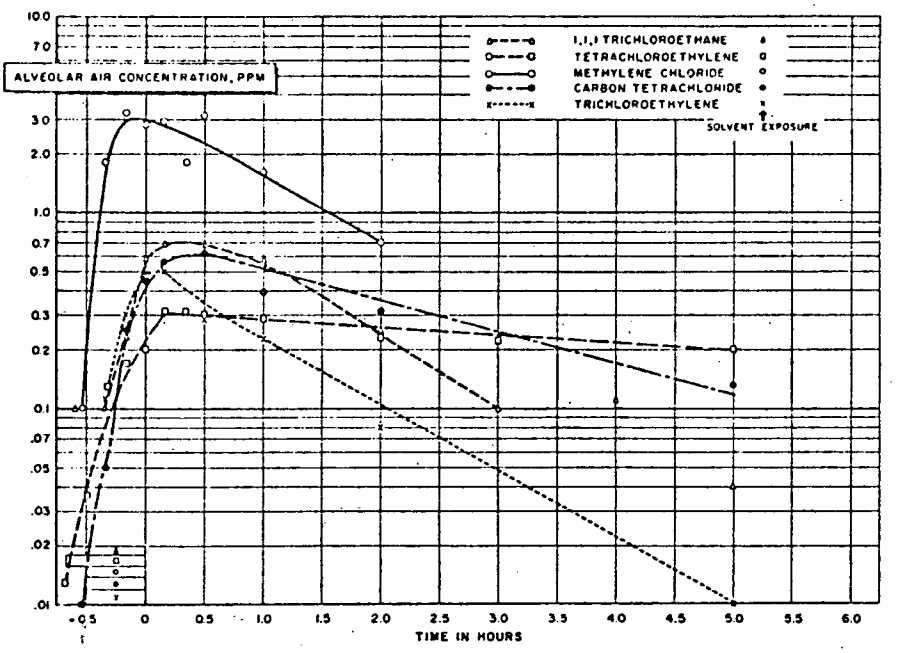
exposure to 100 ppm. After five hours of exposure, the Crawford manual dexterity tests and the Flanagan coordination and arithmetic tests remained normal.

A series of timed, human-skin exposures to methyl chloroform, trichloroethylene, and tetrachloroethylene were run by Stewart and Dodd (1964).

The results of these experiments are as follows:

Human Skin Exposure to Chlorinated Aliphatic Hydrocarbon Solvents

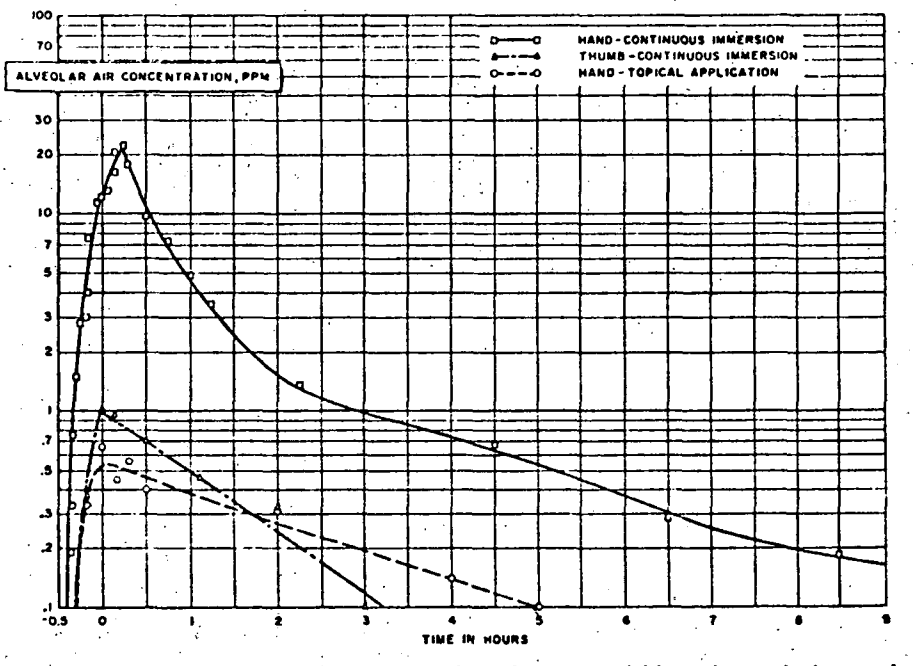
Experiment	No. of Subjects	Solvent	Length of Exposure (min.)	Skin Exposed	Mean Peak Breath Concentration After Exposure	Mean Breath Concentration 2 Hours Afrer Exposure
1	3	Carbon tetrachloride	30 min.	thumb (immersion)	0.64 ppm	0.31 ppm
2	3	Trichloroethylene	30 min.	thumb (immersion)	0.5 ppm	0.08 ppm
3	5	Tetrachloroethylene	40 min.	thumb (immersion)	0.31 ppm	0.23 ppm
4	4	Methylene chloride	30 min.	thumb (immersion)	3.1 ppm	0.69 ppm
5	6	1, 1, 1-Trichloroethane	30 min.	thumb (immersion)	1.0 ppm	0.31 ppm
6	1	1, 1, 1-Trichloroethane	30 min.	hand (immersion)	21.5 ppm	1.55 ppm
7	1	1, 1, 1-Trichloroethane	30 min.	hand topical (application)	0.65 ppm	0.31 ppm



The mean alveolar air concentrations during skin exposure and in the early postexposure period are plotted for the five solvents. The thumb of one hand was immersed in the solvent for the above charted period of time.

Individual Variation in Alveolar Air Concentration Following 30-Minute Skin Exposures

Experiment	Solvent	Solvent Volume Displaced by Thumbs (ml)	Range of Alveolar Air Concentration, ppm							
			During Exposure			Postexposure				
			10 Min.	20 Min.	30 Min.	10 Min.	30 Min.	1 Hour	2 Hours	5 Hours
1	Carbon tetrachloride	15, 15, 17	0.004-0.13	0.04 -0.55	0.11 -0.83	0.27 -0.79	0.45 -0.79	0.24 -0.49	0.19 -0.48	0.12 -0.14
2	Trichloroethylene	15, 20, 20	0 -0.27	0.008-0.51	0.023-0.76	0.04 -0.8	0.10 -0.40	0.13 -0.32	.05 -0.14	0 -0.016
3	Tetrachloroethylene	25, 28, 27, 30, 35	0.02 -0.06	0.11 -0.14	0.17 -0.17	0.26 -0.36	0.26 -0.35	0.23 -0.39	0.18 -0.28	0.16 -0.25
4	Methylene Chloride	20, 21, 24	1.4 -2.4	—	2.3 -3.6	2.1 -4.1	1.1 -6.6	0.6 -4.1	0.26 -1.7	<0.1
5	1, 1, 1-Trichloroethane	19, 20, 22, 25, 25, 28	.10 -.10	0.14 -0.37	0.11 -1.02	0.24 -0.97	0.54 -0.77	0.46 -0.78	0.18 -0.32	0.03 -0.05



The alveolar air concentrations for 1,1,1-trichloroethane during and following 30 minutes of skin exposure are plotted versus time. Topical application of the solvent to the skin of the hand resulted in far less absorption than when the hand was continuously immersed for a similar period of time.

It was concluded, that although the solvents penetrated the skin, methyl chloroform, trichloroethylene and tetrachloroethylene did not do so in toxic amounts.

B. TOXICITY TO NON-HUMAN MAMMALS

1. Acute, Subacute, and Chronic Toxicity

a. Inhalation

Mice were exposed to an atmosphere containing 2500-3000 ppm of methyl chloroform for twenty-four hours. The animals were then sacrificed and the methyl chloroform concentration in the liver was markedly greater than that in the blood. The average methyl chloroform concentration found in the blood was 94 ± 17 mμmol/g and the average concentration found in the liver was 954 ± 65 mμmol/g (Fuller, Olshan, Puri, and Lal, 1970).

Heim (1966) found that the inhalation by mice of 1.8% by volume of trichloroethylene in air anesthetised the animals. The animals were sacrificed at 30 minute and 60 minute intervals after the beginning of the inhalation. An analysis of the livers showed decreased levels of glycogen, glucose, fructose diphosphate, dihydroxyaceteone phosphate, and lactate. Glucose-6-phosphate and pyruvic acid levels were not significantly altered. Creatinine phosphate, ADP, and AMP were reduced while ATP increased, showing that trichloroethylene can disturb the metabolic processes in the mouse liver.

Tetrachloroethylene was found to disturb the metabolic processes in the mouse liver by Ogata, Tomokuni, and Watanabe (1967). After three hours of exposure to 800 ppm of tetrachloroethylene in air, liver ATP had dropped to 46% of normal and remained so for twenty hours. Liver total lipids increased to 134% immediately after exposure and gradually increased to 158% after eight hours.

In comparison studies, trichloroethylene and tetrachloroethylene

were inhaled by mice. Each group of ten mice were given a single four-hour exposure to a series of different concentrations of each compound. Two animals died during trichloroethylene exposure at 6,400 ppm (LD_{50} = 8.450 ppm). At this concentration there was no (or only slight) histologically detectable fatty infiltration of the liver. Tetrachloroethylene caused fatty infiltration of the liver at 440 ppm, but necrosis of the liver cells could not be detected. Trichloroethylene did not produce any significant increase in the amount of extractable liver fat, thereby confirming the histological findings. Tetrachloroethylene caused an increase of the extractable liver fat with increasing concentrations in the air. The authors concluded from this study that trichloroethylene seemed to be less dangerous to the liver than tetrachloroethylene (Kylin, Reichard, Sumegi, and Yllner, 1962).

These same authors (1963) studied this subject further. On histological examination of the livers of mice which had been exposed to trichloroethylene at concentration levels of 1600-3200 ppm, no increase in liver fat was observed. Tetrachloroethylene, on the other hand, induced an increase in liver fat at 400 ppm. Neither agent increased the ornithine carbamoyltransferase activity in serum. The authors concluded that the hepatotoxic effects of trichloroethylene and tetrachloroethylene were in the approximate ratio of 1:10.

Friberg, Kylin, and Nystrom (1953) also concluded from their LD_{50} studies on mice that tetrachloroethylene is more toxic than trichloroethylene.

To determine the lethal dose, groups of eight female white mice were exposed to different concentrations of trichloroethylene or

tetrachloroethylene for four hours. The calculations of LD_{50} showed 8,450 ppm (45.4 mg/L of air) of trichloroethylene and 5,200 ppm (35.4 mg/L of air) of tetrachloroethylene.

To determine the effect upon the central nervous system, two groups of 14 and 15 white mice were exposed to trichloroethylene (12,200 and 6,800 ppm, respectively) and two groups of 14 and 15 white mice were exposed to tetrachloroethylene (12,200 and 6,800 ppm, respectively). According to the stages of narcosis experienced by the animals, the narcotic effect of tetrachloroethylene to mice is greater than that of trichloroethylene. An analysis of variance showed a significant difference ($P = 0.001$).

In long-term inhalation studies, mice were exposed to trichloroethylene at 1600 ppm or to tetrachloroethylene at 200 ppm, for four hours daily, six days per week, for one, two, four, and eight weeks. No external effect on the animals was discernible. No animal died as a result of the exposure. Histological examinations of the livers showed only slight fatty degeneration, and this tended to abate after two weeks. Fatty degeneration was particularly marked for tetrachloroethylene and tended to be more severe with longer exposure. The histologically evaluated degree of fatty degeneration and the amount of liver fat determined by extraction were in agreement; the correlation coefficient was +0.74. The kidneys from the exposed groups and from the control groups showed no appreciable difference (Kylin, Sumegi, and Yllner, 1965).

In a later long-term series of inhalation studies (Prendergast, Jones, Jenkins, and Siegel, 1967), rats, guinea pigs, dogs, and rabbits were

used as experimental animals.

In a thirty-day series of repeated exposures to methyl chloroform (12,060 mg/m^3), no animals died and no toxic signs were visible in the test animals. Gross and histopathologic examinations of brain, heart, lung, liver, spleen, and kidney did not reveal any abnormalities that could be attributed to the exposure.

Continuous exposure to methyl chloroform (2059 mg/m^3) did not result in death or visible toxic signs in the test animals after ninety days. Microscopic examination of tissue showed nonspecific inflammatory changes in the lungs of all species.

During continuous exposure to methyl chloroform (754 mg/m^3), 2/15 of the rats died on days 27 and 77, and 1/3 of the rabbits died on day 38. The survivors exhibited no toxic signs. Varying degrees of lung congestion and pneumonitis were noted in all species and in a number of the controls. In view of the three deaths and the pneumonitis present in the surviving animals, no positive conclusion could be drawn as to whether the effects were associated with the exposure; at the higher exposure of 2059 mg/M^3 no deaths occurred and no pathologic abnormalities were noted.

In repeated exposures to trichloroethylene (3825 mg/M^3), animals were exposed repeatedly for eight hours a day, five days a week, for thirty exposures over a six-week period. No mortalities occurred. Nonspecific inflammatory changes were found on histopathologic examination in the lungs of all animals, but there was no evidence of specific chemically-induced changes in any of the organs which could be attributed to the exposure. Histochemical studies of enzymatic activity were per-

formed on liver tissue from three selected experimental rats; no changes were found.

During continuous exposure to trichloroethylene (189 mg/M^3) for ninety days, no animals died and no visible signs of toxicity were noted. Histopathologic examination of heart, liver, lung, spleen, and kidney tissue showed no indication of chemically induced changes.

b. Ingestion

Trichloroethylene was mixed in olive oil and fed in various concentrations (5-60%; 0.36-4.3 mg/gm) to 200 mice. The mice were sacrificed 72 hours after exposure. The results were as follows: minimal narcotizing dose, 10% or 0.72 mg/gm; minimal lethal dose, 40% or 2.92 mg/gm; minimal hepatotoxic dose, 10% or 0.72 mg/gm; midzonal liver fatty change, 10% or 0.72 mg/gm; central liver fatty change, 12.5% or 0.91 mg/gm; moderate liver changes, 20% or 1.46 mg/gm; and severe liver changes, none observed (Jones, Margolis, and Stephen, 1958).

c. Intraperitoneal administration

Hepatic function and kidney function were determined in mice by sulfobromophthalein retention and serum glutamic-pyruvic transaminase activity following intraperitoneal injections of methyl chloroform, trichloroethylene, and tetrachloroethylene. The solvents were administered in corn oil to deliver a final volume of 0.01 mg/g (Klaassen and Plaa, 1966).

The LD_{50} values after intraperitoneal injection were as follows:
Methyl chloroform in ml/kg, 3.8; in mmole/kg, 37
Trichloroethylene in ml/kg, 2.2; in mmole/kg, 24
Tetrachloroethylene in ml/kg, 2.9; in mmole/kg, 28

These three solvents produced liver dysfunction only near the lethal range when administered intraperitoneally. Tetrachloroethylene was shown to produce hydropic degeneration with a minimal amount of necrosis of the convoluted tubules of the kidneys, while methyl chloroform and trichloroethylene elicited little or no microscopic change.

In later studies conducted by Klaasen and Plaa (1967), intraperitoneal LD_{50} values for dogs were found to be:

Methyl chloroform, 31 mmole/kg

Trichloroethylene, 21 mmole/kg

Tetrachloroethylene, 21 mmole/kg

By this same route, the ED_{50} values for the elevation of serum glutamic-pyruvic transaminase were found to be 8.6 mmole/kg of methyl chloroform, 6.3 mmole/kg of trichloroethylene, and 7.2 mmole/kg of tetrachloroethylene.

The liver dysfunction ED_{50} values as measured by the serum glutamic-pyruvic transaminase activity show that the three solvents are capable of producing some degree of liver dysfunction. Tetrachloroethylene can produce kidney dysfunction in dogs at near lethal doses, as shown by the results of phenolsulfonephthalein excretion tests.

2. Sensitization

No sensitization studies are reported in the literature at hand.

3. Teratogenicity

Nothing is reported on the teratogenic activity of these three solvents.

4. Carcinogenicity

Nothing is reported on any carcinogenic effects of these three solvents.

5. Mutagenicity

No mutagenicity studies have been reported on these solvents.

6. Behavioral effects

Trichloroethylene vapor at concentrations of 400-800 ppm reduced the frequency of the spontaneous alternating behavior of rats. Their running speed was significantly increased at 400-600 ppm but was significantly decreased at 1600 ppm (Zahner, 1961; Grandjean, 1964).

Trichloroethylene vapors when repeatedly inhaled daily by rats produced a specific inhibition of avoidance behavior at concentrations which did not produce motor imbalance. No dose-dependent response was apparent, and results obtained from repeated inhalation of 1568 ppm did not differ from those with 200 ppm. Rats exposed to 4380 ppm were grossly ataxic.

Tetrachloroethylene produced inhibition of the avoidance response only at concentrations which caused frank depression and ataxia (Goldberg, 1964).

Four rats were individually exposed to trichloroethylene vapor (400 γ/L) for a period of 72 to 121 days. In all animals, dynamics of cortical activity were noted with signs of excitation. These effects were demonstrated by a disturbance of differential inhibition and occurrence of positive reflexes with short latent periods and motor unrest in the intervals between stimulations (Khorvat, 1959).

C. TOXICITY TO LOWER ANIMALS AND INSECTS

Trichloroethylene was found to be comparatively non-toxic when applied topically to adult houseflies. Tetrachloroethylene produced tremors with subsequent recovery (Kocher, 1954).

Tetrachloroethylene acts on the nervous system of hookworms by inhibiting the metabolic enzymes of muscle fibers and other somatic cells and induces death by disturbing the respiratory mechanism (Iwata, 1961).

D. TOXICITY TO PLANTS

Phytotoxicity studies were carried out by making water emulsions or solutions of the compounds to be tested and applying them to the foliage of seeding plants with the following results (Gast, 1956):

	Bean		Corn		Cotton		Cucumber		Tomato	
	5%	.5%	5%	.5%	5%	.5%	5%	.5%	5%	.5%
Methyl chloroform	2	0	2.5	0	0.6	0	1	0	1	0
Trichloroethylene	3.5	0	2.5	0	1.5	1	1	0	2	1

Key: 0 = no inury, 1 = slight injury, 2 = moderate injury, 3 = heavy injury, 4 = severe injury or dead plant

E. TOXICITY TO MICROORGANISMS

Tetrachloroethylene was found by Horsfall (1955) to reduce sporulation of Monilinia fructicola.

Trichloroethylene reduces the survival time of Escherichia coli to an extent which is generally proportional to the concentration of the compound used (Horton, Sussman, and Mushin, 1970).

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ION-EXCHANGE RESINS: SUMMARY AND CONCLUSIONS

Although there are available figures which give the amounts of resin materials produded annually in the United States, there are no available figures which give the amounts of ion-exchange resins specifically. Neither were there available figures on the amounts of ion-exchange resins which were used in various applications.

If ion-exchange resins were released into the environment to any extent, their physical and chemical properties would indicate persistence under normal environmental conditions. However, these same properties would argue against toxic hazards. It is unlikely that these resins would find accidental entry into living systems by any route other than oral. The many medical studies that were done in the years shortly following 1950 used human subjects who ingested ion-exchange resins. No consequences were noted other than the expected electrolyte imbalance and the disturbance of acid-base equilibria, and these readjusted to their starting values after the ion-exchange resin was excreted.

However, when a certain ion-exchange resin was fed to female mice during the reproductive cycle, the offspring of these females were below normal in weight and showed some retardation in tooth eruption.

Although commercial ion-exchange resins are insoluble and infusible polymers, they may contain minute quantities of soluble impurities. In most cases rinsing with water is adequate to remove the impurities before certain critical applications. Nothing was found in the literature collected to indicate exactly what these impurities are, nor was any mention made of precautions to be taken in disposing of the rinse water. There are standard procedures for obtaining greater purity, and manufacturer's data sheets contain such information.

According to Food and Drug Regulation 121.1148, extractable substances must be reduced to certain levels. There are established procedures for attaining this degree of purity before applying ion-exchange resins to food treatment.

The potential toxicity of the ion-exchange resins cannot be minimized. Nothing was found in the literature concerning the inhalation of ion-exchange particles or dusts by humans or by animals. Therefore, there is no information on hand relating such inhalation to excretion of the particles or their fate in the respiratory system. Experiments with mice showed that after a suspension of ion-exchange resin was administered intraperitoneally, granuloma formation was induced at sites of phagocytosis by one of the resins used. Particles of other types of resins were phagocytized without further consequence.

In summary, until further information is made available concerning the environmental and biological behavior of the ion-exchange resins, no statements can be made concerning the potential hazard which these agents might present.

ION-EXCHANGE RESINS

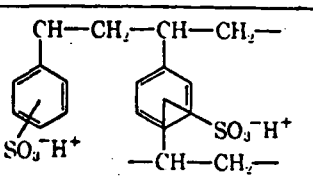
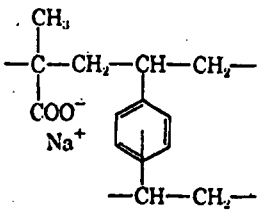
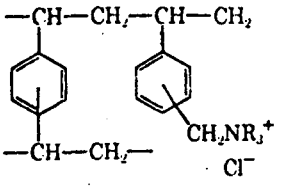
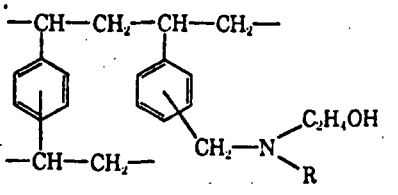
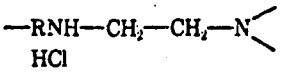
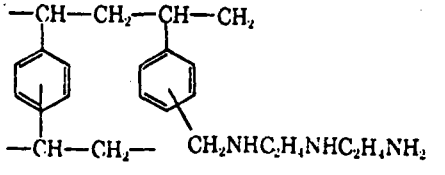
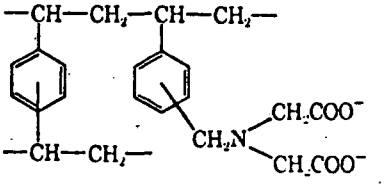
I. PROPERTIES

An ion-exchange resin is a cross-linked polymer which contains either acidic or basic structural units and which can exchange either cations or anions on contact with a solution. Resins are insoluble in all solvents, due to their infinite molecular size which arises from the cross-links. Despite the enormous size of the resin molecules and their complete insolubility, such a polymeric acid or base will exhibit the chemical activity of a monomeric acid or base, subject to the restrictive conditions imposed by the insolubility and the immobility of the massive organic ion (Craig, 1953). These resins are essentially infusible polymers and are resistant to common acids and alkalies. They may also be considered as insoluble acids or bases, the salts of which are also insoluble.

These resins are characterized as anion exchangers (with basic functional groups) and cation exchangers (with acidic functional groups). The various matrices to which these functional groups are attached may be of polystyrene, epoxy-polyamine, phenolic, polyacrylic, and styrene-divinylbenzene frameworks. The resins are beads or granules in physical form with standard mesh range of 16/50 and particle size from 0.3 mm to 1.2 mm.

Strong-acid cation exchangers are normally supplied in the sodium form, weak-acid resins in the hydrogen form, strong-base resins in the chloride form, and weak-base resins in the mixed salt form.

Types of Ion-Exchange Resins and Typical Commercial Products

Type	Chemical characterization	Chemical structure	Selected commercial products
strong acid	sulfonated styrene–divinylbenzene copolymers		Amberlite IR-120 Amberlite 200 Dowex 50 Dowex 50W Dowex MPC-1 Duolite C-20 Duolite C-25 Ionac C-240 Ionac C-250
weak acid	copolymers of an unsaturated carboxylic acid with divinylbenzene or ethylene dimethacrylate		Amberlite IRC-50 Amberlite IRC-84 Duolite CS-101 Ionac C-270
	phenolic condensation products incorporating carboxylic acid groups		Dowex CCR-1 Duolite CS-100
strong base	quaternary ammonium groups fixed to a poly(styrene–divinylbenzene) matrix		*Type I:* Amberlite IRA-400 Amberlite IRA-401 Amberlite IRA-402 Amberlite IRA-900 Duolite A-101-D Duolite ES-111 Dowex 1 Dowex 11 Dowex 21K Ionac A-540
	Type I: derived from trimethylamine		
	Type II: derived from dimethylethanolamine		*Type II:* Amberlite IRA-410 Amberlite IRA-911 Dowex 2 Duolite A-102-D Ionac A-542 Ionac A-550
weak base	condensation products of aliphatic polyamines with formaldehyde, or with ethylene dichloride or epichlorohydrin		Amberlite IRA-68 Dowex 44 Duolite A-7 Ionac A-260
	amines or polyamines fixed to a poly(styrene–divinylbenzene) matrix		Amberlite IR-45 Amberlite IRA-93 Dowex 3 Duolite A-14
miscellaneous chelating resins	iminodiacetate groups fixed to a poly(styrene–divinylbenzene) matrix		Dowex A-1

Source: Snell, 1972

Characteristics of Typical Ion-Exchange Resins

	Cation-exchangers		Anion-exchangers	
	Strongly acidic	Weakly acidic	Strongly basic	Weakly basic
Functional group	Sulfonic	Carboxylic	Quarternary ammonium	Amino
Effect of increasing pH value on capacity	Independent	Increases	Independent	Decreases
Salts	Stable	Hydrolyse on washing	Stable	Hydrolyse on washing
Regeneration of salts to free acid on free base	Exesss of strong acid required	Readily regenerated	Excess of sodium hydroxide required	Readily regenerated with sodium carbonate or ammonia
Rates of exchange	Rapid	Slow unless ionized	Rapid	Slow unless ionized

Source: Pepper, 1952

The chemical stability of the ion-exchange resin as a whole depends both on the stability of the main framework and on the stability of the substituent groups. The sulfonated polystyrene resins are stable at 100°C for long periods in the presence of dilute acids and alkalis. The salts of the strongly basic resins are stable up to 50°C and the free bases possess good stability at room temperature.

II. PRODUCTION

The leading producers of ion-exchange resins in the United States are The Diamond Shamrock Chemical Company, Resinous Products Division (the Duolite exchangers); The Dow Chemical Company (the Dowex exchangers); Ionac Chemical, division of Sybron Corporation (the Sonac exchangers); and Rohm and Haas Company (the Amberlite exchangers).

A styrene-divinylbenzene copolymer is the most frequently used matrix for ion-exchange resins. Polystyrene beads cross-linked with divinylbenzene are modified by chemical reactions to make ion-exchange resins. Cation-exchange resins are produced by sulfonation of the styrene-divinylbenzene copolymer. Anion-exchange resins contain quaternary ammonium or amine groups. There are no available specific descriptions for the manufacture of ion-exchange resins (trade secrets).

Manufacturing sites and production figures for the ion-exchange resins are not readily available.

III. USES

Ion-exchange resins have many very practical uses. Their applicability is attributable to their ability to substitute desirable ions for

undesirable ions. Thus, they are highly favored in water softening. They can eliminate ionic impurities in various media. They are capable of isolating ionic constituents and fractionation (as in ion-exchange chromatography).

Water treatment (both softening and deionization) accounts for the largest single use of these resins. Their utilization in sugar purification is quite extensive. Nearly all impurities associated with sugar in nature are ionic, so the ion-exchange resins are most suitable to purify sugars obtained from beets, cane, corn starch, etc.

Chemical processing is another major area where the ion-exchange resins are used. They are used in the isolation and purification of antibiotics, uranium extraction, and formaldehyde purification.

The ion-exchange resins are also used in the treatment of waste liquors from the pulp and paper industry.

The Federal Food, Drug,,and Cosmetic Act allows many ion-exchange resins to be used in the treatment of food, including potable water, to replace less desirable ions with Cl^-, H^+, OH^- and SO_4^{--}, if the resins are subjected to a preuse treatment by the manufacturer and the resin results in no more than 1 ppm of organic extractive with H_2O, 15% EtOH, and 5% HOAc (Anon, 1964). Saller (1957) demonstrated the biological stability of fruit juices which have been treated with ion-exchange resins. However, the chemical constitution of the juices was so modified, resulting from a reduction in mineral content, that the nutritional value of the juices was substantially minimized.

IV. CURRENT PRACTICES

No specific regulations were found in the literature collected concerning handling, storage, or transport of ion-exchange resins. The inertness of these resins should make their handling problem-free.

V. ENVIRONMENTAL CONTAMINATION

No publications are available which discuss any environmental contamination from the ion-exchange resins. There seem to be no specific recommendations in the literature for the disposal of these resins.

VI. MONITORING AND ANALYSIS

The organic constituents of ion-exchange resins can be decomposed by a wet combustion method using nitric and perchloric acids as an alternative to elution when analyzing small amounts of ion exchange resins for metals (Hoegfeldt, 1954). This method is suitable for both cationic and anionic exchangers, since metals can be retained on anion exchangers as anionic complexes. The samples used were Wofatit KS and Duolite C-3 as examples of phenol formaldehyde resins and dowex 50 and Lewatit S 100 as examples of polystyrene resins. All are cationic and contain sulfonic acid groups. The anion exchanger used was Amberlite-IRA-400, a polystyrene divinylbenzene copolymer containing quaternary ammonium groups. After the wet combustion, the metals were determined radiochemically and polarographically.

The total amount of amino groups, the amount of tertiary amino groups, and the amounts of secondary and tertiary amino groups were

determined by Kopylova (1969) by treating three samples of ion-exchange resins with acetic acid, acetic anhydride, and salicylaldehyde. After being mixed with 0.1 N $HClO_4$ the samples were potentiometrically titrated against 0.05 N potassium hydrogen phthalate solution.

Calmanovici (1965) describes the application of ultraviolet spectroscopy to the analysis of cationic exchange resins.

Ion-exchange resins can be characterized by pyrolysis-gas chromatography. Parrish (1973) gives a method for rapid comparisons of pyrograms of an unknown resin and standard resin using a single resin bead. Polystyrene resins, cation-exchange resins, effects of counterions, effects of crosslinking, effect of capacity, anion-exchange resins, isoporous resins, acrylic resins, and miscellaneous resins are discussed.

Ion-exchangers based on copolymers of styrene and divinylbenzene may contain fragments which are introduced after manufacture. The fragments show structural similarity to the resin and have properties associated with electrolytes. Mass spectrometry can be used to obtain information on the nature of the reactions leading to eventual fragmentations (Armitage, 1973).

The possibility that a given resin preparation may be contaminated by particles having a different charge was investigated by Burger (1967). He developed staining methods to detect such a condition and also to detect variation in cross-linkage.

A review of the standard methods for analyzing ion-exchange resins is given by Snell (1972).

VII. CHEMICAL REACTIVITY

Extremely strong oxidizing agents such as boiling nitric acid or chromic-nitric acid mixtures will rapidly degrade the polymer matrix. Slower degradation with oxygen may be catalytically induced, so ions such as iron, manganese, and copper should be minimized in an oxidizing solution. With cation-exchangers attack is primarily on the polymer backbone; with anion-exchangers attack is on the functional groups. Amine structures may be attacked by low-valent sulfur compounds.

The thermal stability of anion resins is determined by the strength of the C-N bond. A low pH favors higher stability. The quaternary ammonium salts are the least thermostable, limited to 50° C. The tertiary amines are stable up to 100° C. Cation resin stability also depends on pH. Sulfonic acid resins in the acid form are not suitable for use above 150° C in the presence of water. Depolymerization of anhydrous cation resins begins at 250-300° C.

Gamma radiation can cause a variety of simultaneous reactions to occur - polymerization, depolymerization, oxidation, and rupture of C-S or C-N bonds. The results are gas evolution, bead swelling, and weight loss (Wheaton, 1966).

VIII. BIOLOGY

A. ABSORPTION

Because of their molecular magnitude, the ion-exchange resins do not pass through the membranes of living systems. When they are contained within the digestive tract, however, they induce an electrolyte imbalance by exchanging with those ions which normally are absorbed and transported through the body.

This is an advantageous property when the ion-exchange resins are ingested for the purpose of fixing excess sodium which has caused edema, or for regulating potassium levels.

No intestinal damage has been reported from resin ingestion. No evidence of bone decalcification has been observed, other than that which would be expected during the course of the disease being treated (Harthon, 1952).

B. EXCRETION/ELIMINATION

After ingestion, the ion-exchange resins are excreted normally from the intestinal tract. The resin remains essentially unchanged with the only difference at the active sites where ions were exchanged.

After intraperitoneal injections of ion-exchange resin particles into mice, Strecker (1956) found that the resin particles were phagocytized by the mesenchymal cells without substantial cell damage. This was true of sulfonic acid resins and weakly acid resins containing phenolic hydroxyl groups, as well as strongly basic resins. The exception was the weakly

acid Amberlite IRC 50 (carboxylic groups) which induced massive formation of fibrous tissue.

C. TRANSPORT AND DISTRIBUTION

Following intraperitoneal injections into mice, the ion-exchange resins showed no tendency to migrate in the capillary fluids or lymph system (Strecker, 1956).

D. METABOLISM AND METABOLIC EFFECTS

When ion-exchange resin particles were introduced into the mouse peritoneum they did not enter into metabolic reactions but were phagocytized, with the exception of the carboxylic Amberlite IRC 50 which produced tissue reaction in the form of granulomas and fibrous tissue (Strecker, 1956).

In human studies during ingestion of ion-exchange resins, the only effects reported are attributable to electrolyte alterations (Levitt, 1953) and disturbance of acid-base equilibrium (Wolff, 1955; Danowski, 1953).

IX. ENVIRONMENTAL TRANSPORT AND FATE

A. PERSISTENCE AND/OR DEGRADATION

The constitution of the ion-exchange resins indicates that they would persist under normal environmental conditions. There is nothing reported in the literature, however, concerning the persistence or degradation of these compounds.

B. ENVIRONMENTAL TRANSPORT

Nothing was found in the literature to indicate that these resins are transported through the environment to any extent.

C. BIOACCUMULATION

There are no articles in the literature collected on hand which report on inhalation of resin particles or dusts. After ingestion it has been shown that the resins are excreted essentially unchanged through the intestinal system.

Strecker (1956) found that the strongly acidic Dowex 50 (sulfonic acid groups), weakly acidic resins (phenolic OH groups), and the strongly basic Amberlite IRA 410 and Levatit MIH (quaternary ammonium groups) were phagocytized by the mesenchymal cells without essential disturbance to the cells after the intraperitoneal administration of resin particles to mice.

However, the behavior of the weakly acidic Amberlite IRC 50 (carboxylic groups) demonstrated a possibility of a most hazardous mode of bioaccumulation. During the process of its phagocytization, localized nodular granuloma formation was noted.

X. TOXICITY

A. HUMAN TOXICITY

1. Inhalation

Nothing is reported in the literature concerning the inhalation of ion-exchange resin particles or air-borne dust during the manufacturing and handling of the resins.

However, Astanina (1969) reports on toxicity occurring during manufacture of anion-exchange resins from inhalation of some starting products. Workers were afflicted with headaches, nose and larynx dryness, dermatitis, disturbed liver function, and other symptoms. Air analysis showed that chloromethyl methyl ether, trimethylamine, dimethylamine, formaldehyde, benzene, hydrochloric acid, methanol, and dimethoxymethane were present in the air.

2. Ingestion

In the many medical experiments reported, during which patients ingested various amounts of different types of ion-exchance resins, it was not the presence of the resin framework or its contact with the gastrointestinal tract that produced toxic symptoms in the body. The ion-exchange properties of these resins lead to electrolyte imblance and disturbance of the acid-base equilibrium (Danowski, 1953; Wolff, 1955; Levitt, 1953).

There are no reports of any instances in which ion-exchange resins were accidently ingested.

B. TOXICITY TO NON-HUMAN MAMMALS

1. Acute, Subacute, and Chronic Toxicity

In investigations of anion-exchange resins on experimental dental caries and tooth eruption in the rat, the experimental animals received diet supplements of the strongly basic anion-exchange resin Dowex 2X8 in its chloride form ("resin 1"), the weakly basic anion-exchange resin Amberlite XE58 in its hydroxyl form ("resin 2"), and Amberlite XE58

saturated with chloride to nullify its anion-exchange ability ("saturated resin 2").

These resins were toxic when fed to postweaned rats, as evidenced by varying reductions in the rates of growth when compared to control animals. This symptom was accompanied by retardation in the time of eruption of the third molars (Shaw, 1963).

2. Sensitization

Rabbits treated subcutaneously with suspensions of Dowex 50-X4 produced antiserum to this resin. Serum from untreated rabbits and from human subjects gave no agglutination reaction with this resin (Konishi, 1956).

3. Teratogenicity - Reproductive Effects

No teratogenic effects of ion-exchange resins are reported in the literature. However, Shaw (1963) noted some reproductive effects. The offspring of female rats which had been fed weakly basic anion-exchanger Amberlite XE58 (hydroxyl form) had lower weaning weights and slower growth rates than the controls. The offspring of females fed Amberlite XE58 saturated with chloride had weaning weights approximately two-thirds those of the controls.

4. Carcinogenicity

No specific carcinogenic studies were reported in the available literature.

Strecker (1956) reports on granuloma formation following

intraperitoneal administration of weakly acid Amberlite IRC 50 (carboxylic groups) and subsequent phagocytosis by the mesenchymal cells.

5. Mutagenicity

No studies relating ion-exchange resins to mutagenicity are reported in the available literature.

6. Behavioral Effects

No studies were found on the behavioral effects of the ion-exchange resins.

C. TOXICITY TO LOWER ANIMALS

No studies were encountered on the toxicity of the ion-exchange resins toward lower animals.

D. TOXICITY TO PLANTS

Ion-exchange resins have been recommended as agents in the control of aquatic plants, specifically Florida elodea (Martin, 1970). The resins would achieve the desired effect by sequestering or rendering unavailable to the plant certain ions such as manganese and iron. Elodea died in the presence of cation-exchange resin. The exact role of the cation-exchange resin and the identity of the critical metal were not determined.

E. TOXICITY TO MICROORGANISMS

Nothing was available concerning the toxicity of ion-exchange resins toward microorganisms.

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APPENDIX

C. I. Fluorescent Brightener 1

Colour Index Number	C.I. 40630
C. A. Registry Number	[15339-39-6]
Commercial Names	Tinopal BV, BVA, BVS (Ciba-Geigy Corp.)
Chemical Class	4,4'-Bis[4,6-diamino-s-triazin-2-yl)amino]-2,2'-stilbenedisulfonic acid, disodium salt
Molecular Formula	$C_{20}H_{20}N_{12}O_6S_2 \cdot 2Na \cdot (CH_2O)x$
Fluorescence	Bright blue
Properties	Yellowish powder Good solubility in water. Stable to acids and reducing agents. Fastness: Chlorine, moderate; Light, good; Washing, very good
Applications	Cellulose

Ciba-Geigy Corp. reported production and sales of Fluorescent Brightener 1 to the U. S. Tariff Commission in 1972. No production figures are given; they are included in the total brightener production figures.

C. I. Fluorescent Brightener 1:1

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Phorwite GG (Verona Corp.)
Chemical Class	Stilbene derivative
Molecular Formula	Not given in the literature
Fluorescence	Blue
Properties	Fastness: Acids, good; Chlorine, poor; Reducing agents, excellent
Applications	Cellulose

C. I. Fluorescent Brightener 2

This C. I. generic name is discontinued. The brighteners formerly listed under it now appear under C. I. Fluorescent Brightener 1:1.

C. I. Fluorescent Brightener 3

This C. I. generic name is discontinued. The brighteners formerly listed under it now appear under C. I. Fluorescent Brightener 28.

C. I. Fluorescent Brightener 4

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Calcofluor Yellow HEB (American Cyanamid Co.)
Chemical Class	Naphthalimide derivative
Molecular Formula	Not given in the literature
Fluorescence	Yellow
Properties	Insoluble in hydrocarbons and water, very soluble in formic acid, soluble in alcohol and esters
Applications	Nylon, acetate Lacquers

C. I. Fluorescent Brightener 4 is not being manufactured at the present time.

C. I. Fluorescent Brightener 5

Colour Index Number	C.I. 36900
C. A. Registry Number	Not given in the literature
Commercial Names	Fluorescent Purple 2G (Allied Chemical and Dye Corp.)
Chemical Class	Stilbene derivative
Molecular Formula	Not given in the literature
Fluorescence	Reddish-blue
Properties	Good substantivity for cellulose, Fastness: chlorine, poor; peroxide, good; light, satisfactory
Applications	Paper Cellulose

C. I. Fluorescent Brightener 5 is not being manufactured at the present time.

C. I. Fluorescent Brightener 5:1

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Not given in the literature
Chemical Class	Trisazo derivative
Molecular Formula	Not given in the literature
Fluorescence	Reddish-blue
Properties	Good substantivity for cellulose Poor fastness to chlorine
Applications	Paper

C. I. Fluorescent Brightener 6

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Not given in the literature
Chemical Class	Calcofluor White B (American Cyanamid Co.)
Molecular Formula	Not given in the literature
Fluorescence	Blue
Properties	Good fastness to chlorine
Applications	Cellulose

American Cyanamid Co. reported production and sales of Fluorescent Brightener 6 to the U. S. Tariff Commission in 1972. No production figures are given; they are included in the total brightener production figures.

C. I. Fluorescent Brightener 7

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Calcofluor White 4B (American Cyanamid Co.)
Chemical Class	Benzidine sulfone derivative
Molecular Formula	Not given in the literature
Fluorescence	Greenish-blue
Properties	Outstanding fastness to chlorine
Applications	Cellulose

C. I. Fluorescent Brightener 7 is not being manufactured at the present time.

C. I. Fluorescent Brightener 8

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Calcofluor White 5B, 5BT, P5B (American Cyanamid Co.)
Chemical Class	Benzidine sulfone derivative
Molecular Formula	Not given in the literature
Fluorescence	Greenish-blue
Properties	Excellent fastness to chlorine
Applications	Cellulose

American Cyanamid Co. reported production and sales of Fluorescent Brightener 8 to the U.S. Tariff Commission in 1972. No production figures are given; they are included in the total brightener production figures.

C. I. Fluorescent Brightener 9

Colour Index Number	C.I. 40621
C. A. Registry Number	[133-66-4]
Commercial Names	Blancophor HZP, Tintophen CX (GAF Corp.); Blankophor HZP (Farbenfabriken Bayer A.G., Germany); Calcofluor White MR (American Cyanamid Co.); Leukophor DNH (Sandoz Colors and Chemicals); Ryluz PP (Chemopol, Czech.); Tinopal TAS, TASD (Ciba-Geigy Corp.); Whitex SB (Sumitomo Chemical Co., Ltd., Japan)
Chemical Class	4,4'-Bis[(4,6-dianilino-s-triazin-2-yl)amino]-2,2'-stilbenedisulfonic acid, disodium salt
Molecular Formula	$C_{44}H_{36}N_{12}O_6S_2 \cdot 2\ Na$
Fluorescence	Not given in the literature
Properties	Poor fastness to chlorine
Application	Cellulose Detergents

American Cyanamid Co., GAF Corp., and Hilton-Davis Div. of Sterling Drug Corp. reported production and sales of Fluorescent Brightener 9 to the U.S. Tariff Commission in 1972. No production figures are given; they are included in the total brightener production figures.

Production figures which have been reported in the past are:

1965	3,749,000 lbs.
1967	318,000 lbs.
1968	234,000 lbs.
1969	254,000 lbs.

C. I. Fluorescent Brightener 9:1

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Hiltamine White BPK, BPS, EP (Hilton-Davis Div. of Sterling Drug Co.)
Chemical Class	Bistriazinylaminostilbene derivative
Molecular Formula	Not given in the literature
Fluorescence	Not given in the literature
Properties	Poor fastness to chlorine
Applications	Cellulose

C. I. Fluorescent Brightener 10

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Calcofluor White ZRT (American Cyanamid Co.)
Chemical Class	Stilbene derivative
Molecular Formula	Not given in the literature
Fluorescence	Blue
Properties	High substantivity, good solubility, good fastness to light, not fast to chlorine
Applications	Cellulose

C. I. Fluorescent Brightener 10 is not being manufactured at the present time.

C. I. Fluorescent Brightener 11

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Calcofluor White 4R (American Cyanamid Co.)
Chemical Class	Stilbene derivative
Molecular Formula	Not given in the literature
Fluorescence	Reddish-blue
Properties	Excellent fastness to chlorine
Applications	Cellulose

C. I. Fluorescent Brightener 11 is not being manufactured at the present time.

C. I. Fluorescent Brightener 12

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Fluorosol AC (Allied Chemical and Dye Corp.)
Chemical Class	Stilbene derivative
Molecular Formula	Not given in the literature
Fluorescence	Bluish
Properties	Good substantivity and moderate fastness to chlorine
Applications	Cellulose

C. I. Fluorescent Brightener 12 is not being manufactured at the present time.

C. I. Fluorescent Brightener 13

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Fluorosol ACL (Allied Chemical and Dye Corp.)
Chemical Class	Stilbene derivative
Molecular Formula	Not given in the literature
Fluorescence	Bluish
Properties	Moderate fastness to chlorine
Applications	Cellulose

C. I. Fluorescent Brightener 13 is not being manufactured at the present time.

C. I. Fluorescent Brightener 14

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Leucophor RG (Sandoz, Inc.); Whitex RG (Sumitomo Chemical Co., Ltd., Japan)
Chemical Class	Stilbene derivative
Molecular Formula	Not given in the literature
Fluorescence	Bluish
Properties	Greenish-gray powder Compatible with ionic and nonionic softening agents
Applications	Cellulose

C. I. Fluorescent Brightener 15

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Celumyl C (Societe de Produits Chimiques et de Synthese, France); Photine BH, 3BS, CM (Hickson and Welch, Ltd., England); Photine C, C33, UC (Hickson and Welch, Ltd., England; Hickson and Dadajee Private, Ltd., India; S. A. Rovira, Spain)
Chemical Class	Stilbene derivative
Molecular Formula	Not given in the literature
Fluorescence	Blue
Properties	Excellent substantivity, soluble in aqueous media Fastness: Acid, good; Alkali, very good; Chlorine, very good; Dithionite, very good; Peroxide, very good; Light, moderate
Applications	Cellulose Paper

C. I. Fluorescent Brightener 16

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Blancol DP (L.B. Holliday and Co., Ltd., England); Celumyl D (Societe de Produits chimiques et de Synthese, France); Heliofor DP (CIECH, Poland); Photine D, DK (Hickson and Welch, Ltd., England; S. A. Rovira, Spain)
Chemical Class	Stilbene derivative
Molecular Formula	Not given in the literature
Fluorescence	Blue
Properties	Excellent substantivity. Slightly soluble in aqueous detergent solution Fastness: Acid, poor; alkali, very good; Chlorine, good; Dithionite, very good; Peroxide, very good; Light, moderate
Applications	Cellulose Wool Nylon

C. I. Fluorescent Brightener 17

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Celumyl S (Societe de Produits Chimiques et de Synthese, France); Photine S (Hickson and Welch, Ltd., England; S. A. Rovira, Spain)
Chemical Class	Stilbene derivative
Molecular Formula	Not given in the literature
Fluorescence	Blue
Properties	High solubility. Low substantivity. Salt-sensitive. Good stability to dithionite and perborate but poor fastness to chlorine
Applications	Cellulose Paper

C. I. Fluorescent Brightener 17:1

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Photine DN (Hickson and Welch, Ltd., England; S. A. Rovira, Spain)
Chemical Class	Stilbene derivative
Molecular Formula	Not given in the literature
Fluorescence	Blue
Properties	Orange yellow powder High substantivity. Dispensible in water. Fastness: Acid, poor; Alkali, very good; Chlorine, good; Dithionite, very good; Peroxide, very good; Light, moderate
Applications	Nylon

C. I. Fluorescent Brightener 18

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Tinopal SP (Ciba-Geigy Corp.)
Chemical Class	Benzoyldiaminostilbenedisulfonic acid derivative
Molecular Formula	Not given in the literature
Fluorescence	Bright bluish
Properties	Yellow powder Moderately soluble in water Compatible with cationic softeners Stable to resin finishing Very good fastness to chlorine, light, and washing
Applications	Cellulose

C. I. Fluorescent Brightener 18 is not being manufactured at the present time.

C. I. Fluorescent Brightener 19

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Uvitex BT (Ciba-Geigy Corp.)
Chemical Class	Stilbene derivative
Molecular Formula	Not given in the literature
Fluorescence	Yellowish white
Properties	Yellowish white powder Stable to peroxide and dithionite
Applications	Cellulose

C. I. Fluorescent Brightener 19 is not being manufactured at the present time.

C. I. Fluorescent Brightener 20

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Fluotex C2B (Compagnie Francaise des Matieres Colorantes, France)
Chemical Class	Stilbene derivative
Molecular Formula	Not given in the literature
Fluorescence	Not given in the literature
Properties	Good fastness to perborate and peroxide, moderate fastness to chlorine and chlorites
Applications	Cellulose

C. I. Fluorescent Brightener 20 is not being manufactured at the present time.

C. I. Fluorescent Brightener 21

This C. I. generic name is discontinued. The brighteners formerly listed under it now appear under C. I. Fluorescent Brightener 5.

C. I. Fluorescent Brightener 22

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Tinopal 4BMF Liquid (Ciba-Geigy Corp.); Whitex 4BM, LSA (Sumitomo Chemical Co., Ltd., Japan)
Chemical Class	Stilbene derivative
Molecular Formula	Not given in the literature
Fluorescence	Clear Bluish
Properties	Fastness: Chlorine, good; Light, good; Washing, very good
Applications	Cellulose Silk

Ciba-Geigy reported production and sales of Fluorescent Brightener 22 to the U. S. Tariff Commission in 1972. No production figures are given; they are included in the total brightener production figures.

C. I. Fluorescent Brightener 23

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Fluolite BW, C (Imperial Chemical Industries, Ltd., England)
Chemical Class	Stilbene derivative
Molecular Formula	Not given in the literature
Fluorescence	Bluish-violet
Properties	Good fastness to chlorine
Applications	Paper

C. I. Fluorescent Brightener 24

Colour Index Number	Not given in the literature
C. A. Registry Number	[12224-02-1]
Commercial Names	Fluolite HSP Liquid (Imperial Chemical Industries, Ltd., England); Heliofor P (CIECH, Poland); Kayaphor BSN, SN (Nippon Kayaku Co., Ltd., Japan); Mikephor BN (Mitsui Toatsu Chemicals, Inc., Japan); Tinopal 2B, 2BF Liquid, 2BP (Ciba-Geigy Corp.); Whitex BB, BP (Sumitomo Chemical Co., Ltd., Japan)
Chemical Class	Bistriazinylaminostilbenedisulfonic acid derivative
Molecular Formula	Not given in the literature
Fluorescence	Bluish-violet
Properties	Yellow powder Very soluble in water Fastness: Chlorine, very good; Light, good; Washing, very good
Applications	Paper Cellulose

C. I. Fluorescent Brightener 25

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Blancophor SV (GAF Corp.)
Chemical Class	Stilbene derivative
Molecular Formula	Not given in the literature
Fluorescence	Bluish-violet
Properties	Very soluble in cool or warm water
Applications	Cotton, wool, mohair

GAF Corp. reported production and sales of Fluorescent Brightener 25 to the U. S. Tariff Commission in 1972. No figures are given; they are included in the total brightener production figures.

C. I. Fluorescent Brightener 26

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Pontamine White CL (E.I. du Pont de Nemours and Co., Inc.)
Chemical Class	Thiazole derivative
Molecular Formula	Not given in the literature
Fluorescence	Reddish-blue
Properties	Excellent fastness to chlorine
Applications	Cellulose Paper Nylon

C. I. Fluorescent Brightener 26 is not being manufactured at the present time.

C. I. Fluorescent Brightener 27

This C. I. generic name is discontinued. Brighteners formerly listed under it now appear under C. I. Fluorescent Brightener 5:1.

C. I. Fluorescent Brightener 28

Colour Index Number	Not given in the literature
C. A. Registry Number	[4404-43-7] [4193-55-9], disodium salt
Commercial Names	Blancol CFB new (L. B. Holliday and Co., Ltd., England); Blancophor FB, Tintophen FB (GAF Corp.); Calcofluor White PMS, PMW, ST (American Cyanamid Co.); Hiltamine Arctic White CWD (Hilton-Davis Division of Sterling Drug Co.); Paper White BN, BP, Pontamine White BT, BTS (I.E. du Pont de Nemours and Co., Inc.); Tinopal 4BM, 4BMA, 4BMT (Ciba-Geigy Corp.)
Chemical Class	4,4'-Bis[[4-anilino-6-[bis(2-hydroxyethyl)amino]-s-triazin-2-yl]amino]-2,2'-stilbenedisulfonic acid
Molecular Formula	$C_{40}H_{44}N_{12}O_{10}S_2$
Fluorescence	Pale blue
Properties	Canary yellow powder or clear solution Readily soluble in water Excellent stability under reasonable storage conditions Resistant to peroxide and perborate bleaching action; susceptible to hypochlorite bleach Excellent dyeing properties over temperatures of 80°F to 212°F and over pH ranges 5-12.

Applications	ZEFRAN acrylic and cellulosic fibers Shirtings, bed linen, towels, dress goods White ground prints, tapes, braids, white sewing threads, decorative yarns Nylon--gives greener (less red) shade of blue Cold-water laundry formulations Liquid detergents Fabric softeners

American Cyanamid Co., Cincinnati Malacron Chemicals, Inc., E. I. du Pont de Nemours and Co., Inc., Hilton-Davis Chem., Co., and the Verona Division of Baychem Corp. reported production and sales of Fluorescent Brightener 28 to the U. S. Tariff Commission in 1972.

Following are production figures for those years in which this brightener was given separate listing in the U. S. Tariff Commission Reports.

1965	1,515,000 lbs.
1966	1,240,000 lbs.
1967	1,410,000 lbs.
1968	1,420,000 lbs.
1969	1,676,000 lbs.
1970	1,593,000 lbs.
1971	1,574,000 lbs.
1972	1,604,000 lbs.

According to the U. S. Tariff Commission Reports, 4,180 pounds of Fluorescent Brightener 28 were imported into the U. S. in 1972.

C. I. Fluorescent Brightener 29

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Uvitex P (Ciba-Geigy Corp.)
Chemical Class	Not given in the literature
Molecular Formula	Not given in the literature
Fluorescence	Pure blue
Properties	High substantivity for cellulose
Applications	Paper

C. I. Fluorescent Brightener 29 is not being manufactured at the present time.

C. I. Fluorescent Brightener 30

Colour Index Number	C. I. 40600
C. A. Registry Numbers	[17118-51-3], cis [17118-50-2], trans [2606-93-1], disodium salt
Commercial Names	Blancol C (L. B. Holliday and Co., Ltd., England); Blancophor R (GAF Corp.); Blankophor R (Farbenfabriken Bayer A. G., Germany); Blancofor R (Bayer do Brasil Industriea Quinicas S. A., Brazil); Enianil White R (Estabelecimento Nacional Industria de Anilinas S. A., Brazil); Glowhite RRN (Dye-Chem., Ltd., India); Leucophor R (Sandoz, Inc.); Delft White 2RW (Delfland Produkten N.V., Holland); Lumisol RV (Fine Dyestuffs and Chemicals, Ltd., England); Phorwite RN (Verona Corp.); Photine R (Hickson and Welch, Ltd., England; S. A. Rovira, Spain); Tintophen R (GAF Corp.); Whitex R Extra (Sumitomo Chemical Co., Ltd., Japan)

Chemical Class	4,4'-Bis(3-phenylureido)-2,2'-stilbenedisulfonic acid, disodium salt
Molecular Formula	$C_{28}H_{24}N_4O_8S_2 \cdot 2Na$
Fluorescence	Reddish-violet fluorescence in daylight; bluish-violet fluorescence in ultraviolet radiation
Properties	Yellowish powder Poor fastness to chlorine Stable to hydrosulfite
Applications	Cellulose, protein fibers, nylon, wool, paper

GAF Corp. reported production and sales of Fluorescent Brightening Agent 30 to the U.S. Tariff Commission in 1972. No production figures are given; they are included in the total brightener production figures.

C. I. Fluorescent Brightener 31

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Uvitex RSW (Ciba-Geigy Corp.)
Chemical Class	Not given in the literature
Molecular Formula	Not given in the literature
Fluorescence	Not given in the literature
Properties	Good fastness to chlorine
Applications	Mixtures of cellulose, protein fibers, and nylon

C. I. Fluorescent Brightener 31 is not being manufactured at the present time.

C. I. Fluorescent Brightener 32

Colour Index Number	C. I. 40620
C. A. Registry Number	[1264-32-0]
Commercial Names	Blancofor B Extra (Fabricacion Nacional de Colorantes y Explosivos S. A., Spain); Enianil White B (Estabelecimento Nacional Industria de Anilinas, S. A., Brazil); Heliofor BGC (CIECH, Poland); Leukophor B, BCF (Sandoz, Inc.); Whitex B, 3B (Sumitomo Chemical Co., Ltd., Japan); Delft White BS (Delfland Produkten N.V., Holland)
Chemical Class	4,4'-Bis[(4-anilino-6-hydroxy-s-triazin-2-yl)amino]-2,2'-stilbenedisulfonic acid, disodium salt
Molecular Formula	$C_{32}H_{26}N_{10}O_8S_2 \cdot 2Na$
Fluorescence	Bluish
Properties	Yellowish powder Poor fastness to chlorine Good fastness to washing
Applications	Cellulose, protein fibers, nylon

According to the U. S. Tariff Commission Reports, 5,181 pounds of Fluorescent Brightener 32 were imported into the U.S. in 1972.

C. I. Fluorescent Brightening Agent 33

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Name	Blancophor SC (GAF Corp.)
Chemical Class	Not given in the literature
Molecular Formula	Not given in the literature
Fluorescence	Blue (peak at 437 nm)
Properties	Fair fastness to chlorine
Applications	Cellulose, protein fibers, nylon

GAF Corp. reported production and sales of Fluorescent Brightening Agent 33 to the U.S. Tariff Commission in 1972. No production figures are given; they are included in the total brightener production figures.

C. I. Fluorescent Brightening Agent 34

Colour Index Number	C. I. 40605
C. A. Registry Number	[6416-25-7]
Commercial Name	Pontamine White 2GT (E. I. du Pont de Nemours and Co., Inc.)
Chemical Class	4,4'-Bis(2,4-dimethoxybenzamido)-2,2'-stilbenedisulfonic acid, disodium salt
Molecular Formula	$C_{32}H_{30}N_2O_{12}S_2 \cdot 2Na$
Fluorescence	Not given in the literature
Properties	Moderate fastness to chlorine
Applications	Cellulose, protein fibers, nylon

C. I. Fluorescent Brightener 35

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Celumyl B (Societe de Produits Chimiques et de Synthese, France); Photine B (Hickson and Welch, Ltd., England; S. A. Rovira, Spain).
Chemical Class	Stilbene derivative
Molecular Formula	Not given in the literature
Fluorescence	Blue
Properties	Good solubility; moderate substantivity. Stable to alum and size Fastness: Acid, very good; Alkali, very good; Chlorine, good; Dithionite, very good; Peroxide, very good; Light, moderate
Applications	Paper

C. I. Fluorescent Brightener 36

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Blancol 61281 (L. B. Holliday and Co., Ltd., England)
Chemical Class	Balanced anionic-cationic complex
Molecular Formula	Not given in the literature
Fluorescence	Bluish-violet
Properties	Stable to dithionite and peroxide
Applications	Protein fibers, acetate, nylon

C. I. Fluorescent Brightener 37

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Uvitex RT (Ciba-Geigy Corp.); Whitex RT (Sumitomo Chemical Co., Ltd., Japan)
Chemical Class	Stilbene derivative
Molecular Formula	Not given in the literature
Fluorescence	Not given in the literature
Properties	Greenish powder May be used in wash liquors and oxidizing and reducing discharge pastes
Applications	Mixtures of cellulose, protein fibers, and nylon

C. I. Fluorescent Brightener 38

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Uvitex TW (Ciba-Geigy Corp.)
Chemical Class	Not given in the literature
Molecular Formula	Not given in the literature
Fluorescence	Not given in the literature
Properties	Stable to peroxide, chloride, and peracetic acid. Good fastness to light on acetate, polyesters, and acrylics.
Applications	Polyester, acrylic, and protein fibers Nylon, acetate Cellulose

C. I. Fluorescent Brightener 38 is not being manufactured at the present time.

C. I. Fluorescent Brightener 39

C. I. Fluorescent Brightener 39 (Uvitex U, Ciba-Geigy Corp.) is not being manufactured at the present time.

C. I. Fluorescent Brightener 40

Colour Index Number	C. I. 40647
C. A. Registry Number	[7426-67-7]
Commercial Names	Blankophor G (Farbenfabriken Bayer A. G., Germany)
Chemical Class	4,4'-Bis(6-sulfo-2H-naphtho[1,2-d]triazol-2-yl)-2,2'-stilbenedisulfonic acid, tetrasodium salt
Molecular Formula	$C_{34}H_{22}N_6O_{12}S_4 \cdot 4Na$
Fluorescence	Blue
Properties	Stable to peroxide and hydrosulfite Poor fastness to chlorine Good fastness to washing
Applications	Cellulose, protein fibers, polyamide fibers, acetate

C. I. Fluorescent Brightener 40 is not being manufactured at the present time.

C. I. Fluorescent Brightening Agent 41

Colour Index Number	C. I. 49015
C. A. Registry Number	[1483-30-3]
Commercial Name	Uvitex RS (Ciba-Geigy Corp.)
Chemical Class	2-Styrylbenzothiozole
Molecular Formula	$C_{15}H_{11}NS$
Fluorescence	Reddish-blue
Properties	Orange-yellow powder Good fastness to chlorine Stable to hypochlorite
Applications	Cellulose, nylon

C. I. Fluorescent Brightener 42

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Uvitex GS (Ciba-Geigy Corp.)
Chemical Class	Stilbene derivative
Molecular Formula	Not given in the literature
Fluorescence	Green
Properties	Yellow powder Good fastness to chlorine
Applications	Cellulose and Nylon

C. I. Fluorescent Brightener 43

Application and properties are very similar to those of C. I. Fluorescent Brightener 48.

C. I. Fluorescent Brightener 43 is not being manufactured at the present time.

C. I. Fluorescent Brightener 44

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Blancol W (L. B. Holliday and Co., Ltd., England)
Chemical Class	Aminocoumarin derivative
Molecular Formula	Not given in the literature
Fluorescence	Bluish-violet
Properties	Fast to peroxide and to reducing agents
Applications	Protein fibers, acetate

C. I. Fluorescent Brightener 45

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Uvitex SIA (Ciba-Geigy Corp.)
Chemical Class	Heterocyclic
Molecular Formula	Not given in the literature
Fluorescence	Blue
Properties	Very good fastness to chlorine and peroxide
Applications	Cellulose, acetate, nylon

GAF Corp. reported production and sales of Fluorescent Brightener 45 to the U.S. Tariff Commission in 1972. No production figures are given; they are included in the total brightener production figures.

C. I. Fluorescent Brightener 46

Colour Index Number	C. I. 40625
C. A. Registry Numbers	[4434-38-2] [6416-68-8], sodium salt
Commercial Names	Tinopal RBS (Ciba-Geigy Corp.)
Chemical Class	4-(2H-Naphtho[1,2-d]triazol-2-yl)-2-stilbenedisulfonic acid, sodium salt
Molecular Formula	$C_{24}H_{17}N_3O_3S \cdot Na$
Fluorescence	Slightly bluish
Properties	Very good fastness on polyamides
Applications	Soaps, detergents

Ciba-Geigy Corp. reported production and sales of Fluorescent Brightener 46 to the U.S. Tariff Commission in 1972. No production figures are given; they are included in the total brightener production figures.

C. I. Fluorescent Brightener 47

Colour Index Number	Not given in the literature
C. A. Registry Number	Not given in the literature
Commercial Names	Tinopal GS (Ciba-Geigy Corp.)
Chemical Class	Stilbyl-naphthotriazole derivative
Molecular Formula	Not given in the literature
Fluorescence	Greenish
Properties	Orange-yellow powder Very good fastness on polyamides Cellulosic fibers, protein fibers, polyamide fibers
Applications	Soaps, detergents

According to the U.S. Tariff Commission Reports, 33,951 pounds of Fluorescent Brightener 47 were imported into the U.S. in 1972.

C. I. Fluorescent Brightener 48

Colour Index Number	C.I. 40640
C. A. Registry Number	[30587-99-6] [6826-44-4], disodium salt
Commercial Names	Blancol TW (L. B. Holliday and Co., Ltd., England); Fluorosol WS (Allied Chemical and Dye Corp.); Ultraphor WT (Badische Anilin & Soda Fabrik A.G., Germany)
Chemical Class	4,4'-(2-Oxo-4-imidazolin-4,5-diyl)-dibenzenesulfonic acid, disodium salt
Molecular Formula	$C_{15}H_{12}N_2O_7S_2 \cdot 2Na$
Fluorescence	Blue
Properties	Moderate fastness to chlorine Stable to peroxide and to reducing agents
Applications	Protein fibers

According to U.S. Tariff Commission reports, 5,570 lbs. of Fluorescent Brightener 48 were imported into the U.S. in 1972.

Since there is insufficient information to establish correlations between the remainder of the Fluorescent Brightener numbers and molecular formulas, the molecular formula entry will not appear in the following tables (C. I. Fluorescent Brighteners 155, 243, and 245 are exceptions).

There are no Colour Index numbers given for the remaining C. I. Fluorescent Brightener numbers. This item will not appear in the following tables (C. I. Fluorescent Brighteners 74, 243, and 245 are exceptions).

C. I. Fluorescent Brightener 49

C. A. Registry Number	Not given in the literature
Commercial Names	Leucophor BS (Sandoz, Inc.); Rylux BS, BSP (Chemopol, Czech.)
Chemical Class	Bistriazinylaminostilbene
Fluorescence	Bluish
Properties	Maroon-colored liquid Anion-active, very stable to acids and alkalis, light-sensitive in solution
Applications	Cellulose Nylon

Sandoz colors and chemicals reported production and sales of Fluorescent Brightener 49 to the U.S. Tariff Commission in 1972. No figures are given; they are included in the total brightener production figures.

According to the U.S. Tariff Commission, 5,570 lbs. of Fluorescent Brightener 49 were imported into the U.S. in 1972.

C. I. Fluorescent Brightener 50

C. A. Registry Number	Not given in the literature
Commercial Names	Leucophor BB (Sandoz, Inc.)
Chemical Class	Derivative of 4,4'-diamino-2,2'-stilbenedisulfonic acid
Fluorescence	Bluish
Properties	Readily soluble in hot water Fastness: Acid, good; chlorine, moderate; Light, good; Washing, moderate
Applications	Cellulose

C. I. Fluorescent Brightener 51

C. A. Registry Number	Not given in the literature
Commercial Names	Ultraphor APL (Badische Anilin & Soda Fabrik A. G., Germany)
Chemical Class	Naphthalic acid derivative
Fluorescence	Bright blue
Properties	Not substantive to animal fibers or cellulose. Unaffected by hot water. Fastness: Alkali, moderate; Chlorine, light and washing, very good
Applications	Acetate, nylon, acrylic and polyester fibers

C. I. Fluorescent Brightener 51 is not being manufactured at the present time.

C. I. Fluorescent Brightener 52

C. A. Registry Number	Not given in the literature
Commercial Names	Blancol WNS (L. B. Holliday & Co., Ltd., England); Kayaphor WN (Nippon Kayaku Co., Ltd., Japan); Leucophor WS, Leucopur Base (Sandoz, Inc.); Mikephor WS (Mitsui Chemical Industry, Ltd., Japan); Whitex WS (Sumitomo Chemical Co., Ltd., Japan)
Chemical Class	Coumarin derivative
Fluorescence	Bluish violet
Properties	Readily soluble in cold water. Solution susceptible to prolonged exposure to light. Fastness: Washing, moderate to good; Light, moderate
Applications	Protein fibers, acetate, nylon

Sandoz Colors and chemicals reported production and sales of Fluorescent Brightener 52 to the U.S. Tariff Commission in 1972. No production figures are given; they are included in the total brightener production figures.

According to the U.S. Tariff Commission reports, 3,527 lbs. of Fluorescent Brightener 52 were imported into the U.S. in 1972.

C. I. Fluorescent Brightener 53

C. A. Registry Number	Not given in the literature
Commercial Names	Blancol N62532 (L. B. Holliday and Co., Ltd., England)
Chemical Class	Aminocoumarin derivative
Fluorescence	Reddish-blue
Properties	Stable to acids, peroxide, and dithionite
Applications	Protein fibers, nylon, acetate Soaps and detergents

C. I. Fluorescent Brightener 53 is not being manufactured at the present time.

C. I. Fluorescent Brightener 54

C. A. Registry Number	Not given in the literature
Commercial Names	Tinopal WG (Ciba-Geigy Corp.); Whitex WG (Sumitomo Chemical Co., Ltd., Japan)
Chemical Class	Not given in the literature
Fluorescence	Greenish blue
Properties	Good solubility in water. Stable to dithionate Fastness: Light and washing (protein fibers), good; Light (nylon) good; Washing (nylon), fairly good
Applications	Protein fibers, nylon

Ciba-Geigy reported production and sales of Fluorescent Brightener 54 to the U.S. Tariff Commission in 1972. No production figures are given; they are included in the total brightener production figures.

C. I. Fluorescent Brightener 55

C. A. Registry Number	[12768-90-0]
Commercial Names	Tinopal AN (Ciba-Geigy Corp.) Whitex AN (Sumitomo Chemical Co., Ltd., Japan)
Chemical Class	Oxacyanin derivative
Fluorescence	Reddish blue
Properties	White powder Substantive to silk, wook, and cellulose Compatible with cationic softeners Fastness: Chlorine, poor; Light, very good; Washing, moderate
Applications	Acetate, nylon, and acrylic fibers

According to the U.S. Tariff Commission reports, 220 lbs. of Fluorescent Brightener 55 were imported into the U.S. in 1972.

C. I. Fluorescent Brightener 56

This C.I. generic name is discontinued. Those brighteners formerly listed under it now appear under C. I. Fluorescent Brightener 61.

C. I. Fluorescent Brightener 57

C. A. Registry Number	Not given in the literature
Commercial Names	Uvitex W (Ciba-Geigy Corp.)
Chemical Class	Not given in the literature
Fluorescence	Not given in the literature
Properties	Insoluble in water Soluble in organic solvents and fatty acids
Applications	Protein fibers, acetate, nylon

C. I. Fluorescent Brightener 57 is not being manufactured at the present time.

C. I. Fluorescent Brightener 58

C. A. Registry Number	Not given in the literature
Commercial Names	Uvitex NA (Ciba-Geigy Corp.)
Chemical Class	Not given in the literature
Fluorescence	Not given in the literature
Properties	Stable to peroxide and dithionite
Applications	Protein, acetate, nylon, and acrylic fibers

C. I. Fluorescent Brightener 58 is not being manufactured at the present time.

C. I. Fluorescent Brightener 59

C. A. Registry Number	Not given in the literature
Commercial Names	Tinopal RBN (Ciba-Geigy Corp.)
Chemical Class	Stilbene-triazole-sulfonic acid derivative
Fluorescence	Slightly reddish blue
Properties	Greenish-yellow powder Fastness: Chlorine, very good; Light, good; Washing (cellulose), moderate, (nylon) very good
Applications	Protein fibers, nylon

Ciba-Geigy Corp. reported production and sales of Fluorescent Brightener 59 to the U.S. Tariff Commission in 1972. No production figures are given; they are included in the total brightener production figures.

C. I. Fluorescent Brightener 60

C. A. Registry Number	Not given in the literature
Commercial Names	Blancol 61690 (L. B. Holliday and Co., Ltd., England)
Chemical Class	Cationic-nonionic complex
Fluorescence	Bluish violet
Properties	Stable to dithionite and peroxide
Applications	Protein fibers, acetate, nylon

C. I. Fluorescent Brightener 61

C. A. Registry Number	[12224-04-3]
Commercial Names	Blancophor AW, FFG; Tintophen AW, FFG (GAF Corp.); Calcofluor White RW, RWP, SD (American Cyanamid Co.); Uvitex WGS (Ciba-Geigy Corp.)
Chemical Class	Aminocoumarin derivative
Fluorescence	Bluish-violet
Properties	Soluble in aqueous solution and in alcohol; insoluble in water
Applications	Wool, nylon, acetate, silk

Ciba-Geigy reported production and sales to the U.S. Tariff Commission in 1972. No production figures are given; they are included in the total brightener production figures.

C. I. Fluorescent Brightener 62

C. A. Registry Number	Not given in the literature
Commercial Names	Uvitex NL (Ciba-Geigy Corp.)
Chemical Class	Not given in the literature
Fluorescence	Not given in the literature
Properties	Excellent fastness to light
Applications	Nylon

C. I. Fluorescent Brightener 62 is not being manufactured at the present time.

C. I. Fluorescent Brightener 63

C. A. Registry Number	Not given in the literature
Commercial Names	Blancol BT (L. B. Holliday and Co., Ltd., England)
Chemical Class	Triazinylaminostilbene derivative
Fluorescence	Blue
Properties	Effect not cumulative on repeated laundering
Applications	Cellulose

C. I. Fluorescent Brightener 64

This C. I. generic name is discontinued. The brighteners formerly listed under it now appear under C. I. Fluorescent Brightener 28.

C. I. Fluorescent Brightener 65

C. A. Registry Number	Not given in the literature
Commercial Names	Uvitex NSI (Ciba-Geigy Corp.)
Chemical Class	Not given in the literature
Fluorescence	Not given in the literature
Properties	Good fastness to washing
Applications	Cellulose

C. I. Fluorescent Brightener 65 is not being manufactured at the present time.

C. I. Fluorescent Brightener 66

C. A. Registry Number	Not given in the literature
Commercial Names	Blancophor A-3, Tintophen A3 (GAF Corp.)
Chemical Class	Stilbene derivative
Fluorescence	Bluish violet
Properties	Sparingly soluble in water Good fastness to chlorine (on the fiber)
Applications	Soaps

C. I. Fluorescent Brightener 67

C. A. Registry Number	Not given in the literature
Commercial Names	Tintophen CX (General Dyestuff Co.)
Chemical Class	Bistriazinylaminostilbene derivative
Fluorescence	Blue (peak at 440 nm)
Properties	Sparingly soluble in water Disperses well in soap
Applications	Soaps for laundering cotton

C. I. Fluorescent Brightener 67 is not being manufactured at the present time.

C. I. Fluorescent Brightener 68

This C. I. generic name is discontinued. The brighteners formerly listed under it now appear under C. I. Fluorescent Brightener 61.

Cincinnati Malacron Chemicals, Inc. and GAF Corp. reported production and sales of Fluorescent Brightener 68 to the U.S. Tariff Commission in 1972. No figures are given; they are included in the total brightener production figures.

The production figures which have been listed separately in the past for Fluorescent Brightener 68 are as follows:

1960	63,000 lbs.
1961	72,000 lbs.
1962	100,000 lbs.
1964	31,000 lbs.

C. I. Fluorescent Brightener 69

C. A. Registry Number	Not given in the literature
Commercial Names	Leucophor DC (Sandoz Colors and Chemicals)
Chemical Class	Coumarin derivative
Fluorescence	Bluish-violet
Properties	Soluble in hydrocarbons, chlorinated hydrocarbons, acetone, ethyl acetate
Applications	All fibers

C. I. Fluorescent Brightener 70

C. A. Registry Number	Not given in the literature
Commercial Names	Tinopal PCR (Ciba-Geigy Corp.)
Chemical Class	Stilbyl-naphthotriazole derivative
Fluorescence	Bluish
Properties	Very good fastness to light
Applications	Plastics

C. I. Fluorescent Brightener 71

C. A. Registry Number	Not given in the literature
Commercial Names	Blancophor DS-86 (GAF Corp.); Calcofluor White RC (American Cyanamid Co.); Leukophor DU, DUK, Leukopur PAM (Sandoz, Inc.); Photine CBV, CBVS (Hickson and Welch, Ltd., England; S. A. Rovira, Spain)
Chemical Class	Stilbene derivative
Fluorescence	Bluish-violet
Properties	Water dispersible Stable to perborate but not to chlorine Fastness: Acid, poor; Alkali, very good; Chlorine, very good; Dithionate, very good; Peroxide, very good; Light, good
Applications	Laundry compositions containing anionic or nonionic detergents for use on cellulose

American Cyanamid Co. and GAF Corp. reported production and sales of Fluorescent Brightener 71 to the U. S. Tariff Commission in 1972. No figures are given; they are included in the total brightener production figures.

C. I. Fluorescent Brightener 72

C. A. Registry Number	Not given in the literature
Commercial Names	Tinopal E (Ciba-Geigy Corp.)
Chemical Class	Stilbyl-naphthotriazole derivative
Fluorescence	Not given in the literature
Properties	Fastness: Light, good; Washing, very good
Applications	Polyester fibers Plastics

C. I. Fluorescent Brightener 73

C. A. Registry Number	Not given in the literature
Commercial Names	Blancol SS (L. B. Holliday and Co., Ltd., England)
Chemical Class	Trimethyldihydropyridine derivative
Fluorescence	Blue
Properties	Soluble in organic solvents Insoluble in water
Applications	Lacquers and waxes

C. I. Fluorescent Brightener 74

Colour Index Number	C. I. 45550
C. A. Registry Number	Not given in the literature
Commercial Names	Fluorol 5G
Chemical Class	Xanthene derivative
Fluorescence	Greenish-yellow
Properties	Soluble in organic solvents Insoluble in water
Applications	Lacquers and coatings

C. I. Fluorescent Brightener 74 is not being manufactured at the present time.

C. I. Fluorescent Brightener 75

C. A. Registry Number	Not given in the literature
Commercial Names	Fluorescent Brilliant Yellow R (L. B. Holliday and Co., England); Fluorol 7GA (GAF Corp.)
Chemical Class	Xanthene derivative
Fluorescence	Green
Properties	Soluble in organic solvents Insolvent in water
Applications	Lacquers and coatings

According to the U. S. Tariff Commission reports, 1,200 pounds of Fluorescent Brightener 74 were imported into the U. S. in 1972.

C. I. Fluorescent Brightener 76

C. A. Registry Number	Not given in the literature
Commercial Names	Fluorol OB (GAF Corp.)
Chemical Class	Naphthalimide derivative
Fluorescence	Greenish-blue
Properties	Insoluble in water and hydrocarbons Soluble in other organic solvents
Applications	Lacquers and coatings

C. I. Fluorescent Brightener 77

C. A. Registry Number	Not given in the literature
Commercial Names	Fluorol OBR (GAF Corp.)
Chemical Class	Stilbene derivative
Fluorescence	Reddish-blue
Properties	Soluble in organic solvents Insoluble in water
Applications	Lacquers and coatings

C. I. Fluorescent Brightener 77 is not being manufactured at the present time.

C. I. Fluorescent Brightener 78

C. A. Registry Number	Not given in the literature
Commercial Names	Blancol 62531 (L. B. Holliday and Co., Ltd., England)
Chemical Class	Aminocoumarin derivative
Fluorescence	Bluish-violet
Properties	Soluble in organic solvents Insoluble in water
Applications	Lacquers, coatings, shellac Plastics

C. I. Fluorescent Brightener 79

C. A. Registry Number	[12676-63-0]
Commercial Names	Leukophor A, AC (Sandoz, Inc.); Delft White BSM (Delfland Produkten N.V., Holland)
Chemical Class	Not given in the literature
Fluorescence	Not given in the literature
Properties	Good fastness to acid, alkali, and chlorine
Applications	Cellulose

C. I. Fluorescent Brightener 80

C. A. Registry Number	Not given in the literature
Commercial Names	Delft White GS (Delfland Produkten N.V., Holland)
Chemical Class	Not given in the literature
Fluorescence	Yellowish-green
Properties	Not given in the literature
Applications	Cellulose

C. I. Fluorescent Brightener 81

C. A. Registry Number	Not given in the literature
Commercial Names	Delft White BSW (Delfland Produkten N.V. (Holland)
Chemical Class	Not given in the literature
Fluorescence	Not given in the literature
Properties	Good fastness to acid, alkali, and chlorine
Applications	Cellulose

C. I. Fluorescent Brightener 82

C. A. Registry Number	Not given in the literature
Commercial Names	Delft White RS (Delfland Produkten N.V., Holland)
Chemical Class	Stilbene derivative
Fluorescence	Not given in the literature
Properties	Fastness: Acid, good; alkali, excellent; Heat, good; Light, good
Applications	Cellulose

C. I. Fluorescent Brightener 83

C. A. Registry Number	Not given in the literature
Commercial Names	Citalba B (Aziende Colori Nazionali Affini A.C.N.A., Italy)
Chemical Class	Stilbene derivative
Fluorescence	Bluish
Properties	Poor fastness to chlorine; stable to dithionite and peroxide
Applications	Protein fibers, nylon Cellulose

C. I. Fluorescent Brightener 83 is not being manufactured at the present time.

C. I. Fluorescent Brightener 84

C. A. Registry Number	[12224-05-4]
Commercial Names	Kayaphor A, AK (Nippon Kayaku Co., Ltd., Japan); Mikephor BA (Mitsui Toatsu Chemicals, Inc., Japan); Whitex BC, BCK, BO, BT (Sumitomo Chemical Co., Ltd., Japan)
Chemical Class	Bistriazinylaminostilbene derivative
Fluorescence	Bluish-violet
Properties	Good solubility in water Good fastness to chlorine, light, peroxide, and washing
Applications	Cellulose Paper

C. I. Fluorescent Brightener 85

C. A. Registry Number	[12224-06-5]
Commercial Names	Kayaphor AB, B, BB, BNK, LB (Nippon Kayaku Co., Ltd., Japan); Leukophor DK (Sandoz Colors and Chemicals); Mikephor BP, BX, BX Extra 200 (Mitsui Toatsu Chemicals, Inc., Japan); Whitex BH, BK, LBH (Sumitomo Chemical Co., Ltd., Japan)
Chemical Class	Bistriazinylaminostilbene derivative
Fluorescence	Bluish-violet
Properties	Not given in the literature
Applications	Cellulose Paper

C. I. Fluorescent Brightener 86

C. A. Registry Number	[12224-07-6]
Commercial Names	Kayaphor FB (Nippon Kayaku Co., Ltd., Japan); Mikephor BI (Mitsui Toatsu Chemicals, Inc., Japan); Whitex BN, LSB (Sumitomo Chemical Co., Ltd., Japan)
Chemical Class	Bistriazinylaminostilbene derivative
Fluorescence	Bluish-violet
Properties	Good solubility in water Good fastness to chlorine, light, peroxide, and washing
Applications	Cellulose, paper Soaps, detergents

C. I. Fluorescent Brightener 87

C. A. Registry Number	Not given in the literature
Commercial Names	Kayaphor S (Nippon Kayaku Co., Ltd., Japan)
Chemical Class	Bistriazinylaminostilbene derivative
Flourescence	Bluish-violet
Properties	Very good solubility in water Good fastness to chlorine, light, peroxide, and washing
Applications	Cellulose Paper

C. I. Fluorescent Brightener 88

This C. I. generic name is discontinued. The brighteners formerly listed under it now appear under C. I. Fluorescent Brightener 24.

C. I. Fluorescent Brightener 89

This C. I. generic name is discontinued. The brighteners formerly listed under it now appear under C. I. Fluorescent Brightener 52.

C. I. Fluorescent Brightener 90

C. A. Registry Number	[12224-08-7]
Commercial Names	Kayaphor AS, ASC (Nippon Kayaku Co., Ltd., Japan); Mikephor BS (Mitsui Toatsu Chemicals, Inc., Japan); Whitex BF, BOF, HP (Sumitomo Chemical Co., Ltd., Japan)
Chemical Class	Bistriazinylaminostilbene derivative
Fluorescence	Bluish-violet
Properties	Fairly soluble in water Good fastness to chlorine, light, and peroxide
Applications	Nylon Cellulose Paper

C. I. Fluorescent Brightener 91

C. A. Registry Number	Not given in the literature
Commercial Names	Kayalight B (Nippon Kayaku Co., Ltd., Japan)
Chemical Class	Coumarin derivative
Fluorescence	Bluish-violet
Properties	Very good solubility in organic solvents Poor solubility in water Moderately fast to light and washing
Applications	Wool, silk Synthetic resins

C. I. Fluorescent Brightener 92

This C. I. generic name is discontinued. The brightener formerly listed under it now appears under C. I. Fluorescent Brightener 84.

C. I. Fluorescent Brightener 93

This C. I. generic name is discontinued. The brightener formerly listed under it now appears under C. I. Fluorescent Brightener 24.

C. I. Fluorescent Brightener 94

C. A. Registry Number	Not given in the literature
Commercial Names	Mikephor FP (Mitsui Toatsu Chemicals, Inc., Japan)
Chemical Class	Triazinylstilbene derivative
Fluorescence	Bright blue
Properties	Not given in the literature
Applications	Cellulose

C. I. Fluorescent Brightener 94 is not being manufactured at the present time.

C. I. Fluorescent Brightener 95

This C. I. generic name is discontinued. The brightener formerly listed under it now appears under C. I. Fluorescent Brightener 85.

C. I. Fluorescent Brightener 96

This C. I. generic name is discontinued. The brightener formerly listed under it now appears under C. I. Fluorescent Brightener 85.

C. I. Fluorescent Brightener 97

C. A. Registry Number	Not given in the literature
Commercial Names	Mikephor BH-2 (Mitsui Toatsu Chemicals Inc., Japan)
Chemical Class	Bistriazinylamino-stilbenedisulfonic acid derivative
Fluorescence	Bright blue
Properties	Not given in the literature
Applications	Cellulose

C. I. Fluorescent Brightener 97 is not being manufactured at the present time.

C. I. Fluorescent Brightener 98

C. A. Registry Number	Not given in the literature
Commercial Names	Fluolite L Tablets (Imperial Chemical Industries, Ltd., England)
Chemical Class	Stilbene derivative
Fluorescence	Blue
Properties	Soluble in water but not in organic solvents Fastness: Alkali, very good; Chlorine, good; Dithionite, very good; Peroxide, very good; Washing, very good
Applications	Cellulose

C. I. Fluorescent Brightener 98 is not being manufactured at the present time.

C. I. Fluorescent Brightener 99

C. A. Registry Number	Not given in the literature
Commercial Names	Fluolite MP Liquid (Imperial Chemical Industries, Ltd., England)
Chemical Class	Stilbene derivative
Fluorescence	Blue
Properties	Soluble in water Insoluble in organic solvents Fastness: Acid, good; Alkali, very good; Chlorine, good; Dithionite, very good; Peroxide, very good; Washing, very good
Applications	Cellulose Paper

C. I. Fluorescent Brightener 100

C. A. Registry Number	[12270-49-4]
Commercial Names	Fluolite XNR (Imperial Chemical Industries, Ltd., England)
Chemical Class	Stilbene derivative
Fluorescence	Reddish-blue
Properties	Soluble in water Insoluble in organic solvents Fastness: Acid, very good; Alkali, very good; Chlorine, good; Dithionite, very good; Peroxide, very good; Washing, good
Applications	Protein fibers, nylon Cellulose Paper

C. I. Fluorescent Brightener 101

C. A. Registry Number	Not given in the literature
Commercial Names	Tinopal ACA (Ciba-Geigy Corp.)
Chemical Class	Not given in the literature
Fluorescence	Reddish-blue
Properties	Fastness: Acid, very good; Alkali, good; Chlorine, good; Dithionite, good; Light, moderate; Peroxide, Moderate; Washing, good
Applications	Acrylic fibers

C. I. Fluorescent Brightener 102

C. A. Registry Number	[12224-09-8]
Commercial Names	Paper White SP, SPSW, Pontamine White SP Solution (E. I. du Pont de Nemours and Co., Inc.)
Chemical Class	Stilbene derivative
Fluorescence	Greenish
Properties	Soluble in water Stable to alum
Applications	Paper

E. I. du Pont de Nemours and Co. and Verona Corp. reported production and sales of Fluorescent Brightener 102 to the U. S. Tariff Commission in 1972. No production figures are given; they are included in the total brightener production figures.

C. I. Fluorescent Brightener 103

C. A. Registry Number	Not given in the literature
Commercial Names	Tinopal BST (Ciba-Geigy Corp.)
Chemical Class	Triazinylstilbene derivative
Fluorescence	Slightly bluish
Properties	Not given in the literature
Applications	Cellulose

According to the U. S. Tariff Commission reports, 220 pounds of Fluorescent Brightener 103 were imported into the U. S. in 1972.

C. I. Fluorescent Brightener 104

C. A. Registry Number	[12224-10-1]
Commercial Names	Kayaphor PN (Nippon Kayaku Co., Ltd., Japan); Tinopal RP (Ciba-Geigy Corp.); Whitex RP (Sumitomo Chemical Co., Ltd., Japan)
Chemical Class	Bistriazinylaminostilbene derivative
Fluorescence	Bluish-violet
Properties	Very good solubility in water Fastness: Acid, very good; Alkali, very good; Chlorine, good; Dithionite, very good; Light, very good; Peroxide, good; Washing, good
Applications	Wool, silk, nylon Cellulose-wool unions; Cellulose-nylon unions

C. I. Fluorescent Brightener 105

C. A. Registry Number	Not given in the literature
Commercial Names	Calcofluor White CW (American Cyanamid Co.)
Chemical Class	Triazinylstilbene derivative
Fluorescence	Bluish-white
Properties	Miscible in water in all proportions Insoluble in petroleum solvents Fastness: Acid, good; Alkali, good; Chlorine, poor; Dithionite, very good; Light, good
Applications	Nylon Cellulose Paper

C. I. Fluorescent Brightener 105 is not being manufactured at the present time.

C. I. Fluorescent Brightener 106

This C. I. generic name is discontinued.

C. I. Fluorescent Brightener 107

C. A. Registry Number	Not given in the literature
Commercial Names	Blancophor GS-33, Tintophen GS-33 (GAF Corp.)
Chemical Class	Stilbene derivative
Fluorescence	Bright greenish-blue
Properties	Levels well
Applications	Cellulose

C. I. Fluorescent Brightener 108

C. A. Registry Number	Not given in the literature
Commercial Names	Blancophor CB-32, Tintophen CB-32 (GAF Corp.)
Chemical Class	Stilbene derivative
Fluorescence	Blue
Properties	Levels well
Applications	Cellulose

GAF Corp. reported production and sales of Fluorescent Brightener 108 to the U. S. Tariff Commission in 1972. No figures are given; they are included in the total brightener production figures.

C. I. Fluorescent Brightener 109

C. A. Registry Number	Not given in the literature
Commercial Names	Blancophor SB, Tintophen SB (GAF Corp.)
Chemical Class	Stilbene derivative
Fluorescence	Blue
Properties	Very good solubility in water
Applications	Paper

GAF Corp. reported production and sales of Fluorescent Brightener 109 to the U.S. Tariff Commission in 1972. No production figures are given; they are included in the total brightener production figures.

C. I. Fluorescent Brightener 110

C. A. Registry Number	Not given in the literature
Commercial Names	Blancophor HL-32, HL-72, Tintophen HL-32, HL-72 (GAF Corp.)
Chemical Class	Stilbene derivative
Fluorescence	Bright greenish-blue
Properties	Water soluble Insensitive to pH change
Applications	Paper

C. I. Fluorescent Brightener 111

C. A. Registry Number	Not given in the literature
Commercial Names	Whitening Agent Wolfen BV, BVP, BVP 60/100 (Farbenfabriken Wolfen, Germany)
Chemical Class	
Flourescence	Bluish-violet
Properties	Soluble in water; Anion-active Fastness: Acid, sensitive; Chlorine, moderate; Dithionite, good; Light, very good; Washing, good
Applications	Nylon Cellulose

C. I. Fluorescent Brightener 112

C. A. Registry Number	[12270-50-7]
Commercial Names	Blankophor ACF (Farbenfabriken Bayer A. G., Germany); Ultraphor NA (Badische Anilin & Soda Fabrik A. G., Germany)
Chemical Class	Coumarin derivative
Fluorescence	Blue
Properties	Soluble in hot water Fastness: Acid, very good; Alkali, very good; Chlorine, very good; Dithionite, very good; Peroxide, Very good; Washing, very good
Applications	Acetate

According to the U. S. Tariff Commission reports, 250 pounds of Fluorescent Brightener 112 were imported into the U. S. in 1972.

C. I. Fluorescent Brightener 113

C. A. Registry Number	Not given in the literature
Commercial Names	Blankophor BA (Farbenfabriken Bayer A. G., Germany)
Chemical Class	Stilbene derivative
Fluorescence	Bright bluish-violet
Properties	Yellowish white powder Water soluble Fastness: Acid, moderate; Alkali, very good; Chlorine, good; Dithionite, very good; Light, good; Peroxide, very good; Washing, very good
Applications	Cellulose

C. I. Fluorescent Brightener 114

C. A. Registry Number	[12270-51-8]
Commercial Names	Blancofor BBV (Fabricacion Nacional de Colorantes y Explosivos, S. A., Spain); Blankophor BBV Extra (Farbenfabriken Bayer, A. G., Germany); Heliofor CAS (CEICH, Poland); Ultraphor GPB (Badische Anilin & Soda Fabrik A. G., Germany)
Chemical Class	Stilbene derivative
Fluorescence	Bluish-violet
Properties	Greenish-yellow powder Water soluble Fastness: Acid, very good; Alkali, very good; Chlorine, good; Dithionite, very good; Light, good; Peroxide, very good; Washing, good
Applications	Cellulose

Verona Corp. reported production and sales of Fluorescent Brightener 114 to the U. S. Tariff Commission in 1970. No production figures are given; they are included in the total brightener figures.

C. I. Fluorescent Brightener 115

C. A. Registry Number	Not given in the literature
Commercial Names	Blankophor BE Extra (Farbenfabriken Bayer A. G., Germany)
Chemical Class	Stilbene derivative
Fluorescence	Bluish-violet
Properties	Water soluble Fastness: Acid, moderate; Alkali, very good; Chlorine, good; Dithionite, very good; Light, good; Peroxide, very good; Washing, good
Applications	Cellulose

C. I. Fluorescent Brightener 116

C. A. Registry Number	Not given in the literature
Commercial Names	Blancofor BP (Fabricacion Nacional de Colorantes y Explosivos S. A., Spain) Blankophor BP Extra (Farbenfabriken Bayer A. G., Germany)
Chemical Class	Stilbene derivative
Fluorescence	Blue
Properties	Fastness: Acid, moderate; Alkali, moderate; Dithionite, very good; Light, good; Peroxide, very good
Applications	Paper

C. I. Fluorescent Brightener 117

C. A. Registry Number	Not given in the literature
Commercial Names	Blancofor BPN (Fabricacion Nacional de Colorantes y Explosivos S. A., Spain) Blankophor BPN Extra (Farbenfabriken Bayer A. G., Germany)
Chemical Class	Stilbene derivative
Fluorescence	Blue
Properties	Water soluble, insoluble in organic solvents Fastness: Acid, good; Alkali, moderate, Dithionite, very good; Light, good; Peroxide, very good
Applications	Paper

C. I. Fluorescent Brightener 118

C. A. Registry Number	Not given in the literature
Commercial Names	Blankophor CE (Farbenfabriken Bayer A. G., Germany)
Chemical Class	Stilbene derivative
Fluorescence	Bluish-green
Properties	Water soluble Fastness: Acid, very good; Alkali, very good; Chlorine, very good; Dithionite, very good; Light, good; Peroxide, very good; Washing, moderate
Applications	Cellulose

C. I. Fluorescent Brightener 119

C. A. Registry Number	[12270-52-9]
Commercial Names	Blankophor REV (Farbenfabriken Bayer A. G., Germany); Ultraphor RPB (Badische Anilin & Soda Fabrik A. G., Germany)
Chemical Class	Stilbene derivative
Fluorescence	Reddish-violet
Properties	Water soluble Fastness: Acid, very good; Alkali, very good; Chlorine, good; Dithionite, very good; Light, good; Peroxide, very good; Washing, good
Applications	Cellulose

According to the U. S. Tariff Commission reports, 125,040 pounds of Fluorescent Brightener 119 was imported into the U. S. in 1972.

C. I. Fluorescent Brightener 120

This C. I. generic name is discontinued. The fluorescent brightener formerly listed under it now appears under C. I. Fluorescent Brightener 104.

C. I. Fluorescent Brightener 121

C. A. Registry Number	[12224-11-2]
Commercial Names	Blancofor BBH (Fabricacion Nacional de Colorantes y Explosivos S. A., Spain); Blankophor DCB (Farbenfabriken Bayer A. G., Germany)
Chemical Class	Stilbene derivative
Fluorescence	Bright bluish-violet
Properties	Fastness: Acid, very good; Alkali, very good; Light (acrylic) very good, (acetate and nylon) good; Washing, very good
Applications	Acetate, triacetate, nylon, acrylics

According to the U. S. Tariff Commission reports, 79,210 pounds of Fluorescent Brightener 121 were imported into the U. S. in 1972.

C. I. Fluorescent Brightener 122

This C. I. generic name is discontinued.

C. I. Fluorescent Brightener 123

C. A. Registry Number	Not given in the literature
Commercial Names	Rylux D (Chemapol, Czech.)
Chemical Class	Morpholine derivative
Fluorescence	Bright blue
Properties	Not given in the literature
Applications	Not given in the literature

C. I. Fluorescent Brightener 124

C. A. Registry Number	Not given in the literature
Commercial Names	Blankophor SN (Farbenfabriken Bayer A. G., Germany)
Chemical Class	Pyrazolone derivative
Fluorescence	Bluish
Properties	Not given in the literature
Applications	Soap

C. I. Fluorescent Brightener 125

C. A. Registry Number	Not given in the literature
Commercial Names	Calcofluor White EDW, PUM (American Cyanamid Co.)
Chemical Class	Triazinylstilbene derivative
Fluorescence	Slightly reddish-blue
Properties	Amber liquid Specific gravity 1.23 Fluorescent emission at 440 mu Compatible with anionic and nonionic materials Miscible with water in all proportions
Applications	Padding with resins Cellulose Nylon

American Cyanamid Co. reported production and sales of Fluorescent Brightener 125 to the U. S. Tariff Commission in 1972. No production figures are given; they are included in the total brightener production figures.

C. I. Fluorescent Brightener 126

C. A. Registry Number	Not given in the literature
Commercial Names	Hiltamine Arctic Paper White (Hilton-Davis Div. of Sterling Drug Co.)
Chemical Class	Triazinylstilbene derivative
Fluorescence	Bluish-violet
Properties	Liquid in form; anionic in nature Fastness: Acid, very good; Alkali, good; Chlorine, moderate; Dithionite, good; Light, poor; Peroxide, good; Washing, good
Applications	Suitable for use with practically all paper-making additives Cellulose

Hilton-Davis Div. of Sterling Drug Corp. reported production and sales of Fluorescent Brightener 126 to the U. S. Tariff Commission in 1972. No production figures are given; they are included in the total brightener production figures.

C. I. Fluorescent Brightener 127

C. A. Registry Number	Not given in the literature
Commercial Names	Hiltamine Arctic White Acid Stable (Hilton-Davis Div. of Sterling Drug Co.)
Chemical Class	Triazinylstilbene derivative
Fluorescence	Bluish-violet
Properties	Liquid in form; anionic in nature pH 8.5-9.5 Substantive to all cellulosic fibers Compatible with most anionic and nonionic textile additives
Applications	Cellulose Textiles, silk, acetate Exhaust padding Thermosetting resin finishes

C. I. Fluorescent Brightener 128

C. A. Registry Number	Not given in the literature
Commercial Names	Hiltamine Arctic White DML (Hilton-Davis Div. of Sterling Drug Co.)
Chemical Class	Triazinylstilbene derivative
Fluorescence	Bluish-violet
Properties	Liquid in form; anionic in nature pH 8.5-10.5 Substantive to all cellulosic fibers Compatible with cationic, anionic, and nonionic softeners
Applications	Cellulose Paper Silk, acetate Fabric softeners

Hilton-Davis Div. of Sterling Drug Corp. reported production and sales of Fluorescent Brightener 128 to the U. S. Tariff Commission in 1972. No production figures are given; they are included in the total brightener production figures.

C. I. Fluorescent Brightener 129

C. A. Registry Number	Not given in the literature
Commercial Names	Hiltamine Arctic White DP (Hilton-Davis Div. of Sterling Drug Co.)
Chemical Class	Stilbene derivative
Fluorescence	Bluish-violet
Properties	Fastness: Acid, good; Alkali, good; Chlorine, moderate; Dithionite, good; Peroxide, good
Applications	Cellulose, silk, nylon, acetate

C. I. Fluorescent Brightener 129 is not being manufactured at the present time.

C. I. Fluorescent Brightener 130

C. A. Registry Number	Not given in the literature
Commercial Names	Calcofluor White LD (American Cyanamid Co.); Hiltamine Arctic White N (Hilton-Davis Div. of Sterling Drug Co.)
Chemical Class	Coumarin derivative
Fluorescence	Violet
Properties	Nonionic in nature Insoluble in water; soluble in alcohol, glycols, and Cellusolve
Applications	Wool, nylon, silk, acetate, triacetate, and acrylic fibers Protein fibers

American Cyanamid Co. reported production and sales of Fluorescent Brightener 130 to the U. S. Tariff Commission in 1972. No production figures are given; they are included in the total brightener production figures.

C. I. Fluorescent Brightener 130:1

C. A. Registry Number	Not given in the literature
Commercial Names	Hiltamine Arctic White WNOA (Hilton-Davis Div. of Sterling Drug Co.)
Chemical Class	Coumarin derivative
Fluorescence	Not given in the literature
Properties	Nonionic in nature Readily dissolves in warm water
Applications	Detergent formulation Polyamides, acetate, triacetate

C. I. Fluorescent Brightener 131

C. A. Registry Number	Not given in the literature
Commercial Names	Hiltamine Arctic White SP New (Hilton-Davis Div. of Sterling Drug Co.)
Chemical Class	Stilbene derivative
Fluorescence	Bluish-violet
Properties	Fastness: Acid, good; Alkali, good; Chlorine, moderate; Dithionite, good; Light, poor; Peroxide, good; Washing, good
Applications	Cellulose, silk, acetate

C. I. Fluorescent Brightener 131 is not being manufactured at the present time.

C. I. Fluorescent Brightener 132

C. A. Registry Number	Not given in the literature
Commercial Names	Hiltamine White FMC, Mirawhite White FAC (Hilton-Davis Div. of Sterling Drug Co.)
Chemical Class	Stilbene derivative
Fluorescence	Blue
Properties	Soluble in glycols and Cellosolve Fastness: Acid, poor; Alkali, very good; Chlorine, very good; Hydrosulphite, very good; Light, good; Peroxide, very good; Washing, very good
Applications	Cellulose, silk, acetate, acrylics

C. I. Fluorescent Brightener 133

C. A. Registry Number	Not given in the literature
Commercial Names	Uvitex A (Ciba-Geigy Corp.)
Chemical Class	Heterocyclic
Fluorescence	Blue
Properties	Very good fastness to light and washing
Applications	Acrylic staple fiber

C. I. Fluorescent Brightener 134

C. A. Registry Number	Not given in the literature
Commercial Names	Ultraphor BP (Badische Anilin & Soda Fabrik A. G., Germany); Uvitex CF (Ciba-Geigy Corp.)
Chemical Class	Stilbene derivative
Fluorescence	Blue
Properties	Good solubility in water. Stable to acids, peroxide bleach liquors and reducing agents Fastness: Chlorine, good; Light, good; Washing, very good
Applications	Cellulose, nylon, wool

According to the U. S. Tariff Commission reports, 25,792 pounds of Fluorescent Brightener 134 were imported into the U. S. in 1972.

C. I. Fluorescent Brightener 135

C. A. Registry Number	[12224-12-3]
Commercial Names	Uvitex ERN Conc. P (Ciba-Geigy Corp.); Whitex ERN (Sumitomo Chemical Co., Ltd., Japan)
Chemical Class	Heterocyclic
Fluorescence	Reddish-blue
Properties	Excellent fastness to light and very good fastness to washing on polyester. Stable in chlorite bleach liquors and peracetic acid
Applications	Polyester, acetate, nylon, polyvinyl fibers

C. I. Fluorescent Brightener 136

C. A. Registry Number	Not given in the literature
Commercial Names	Uvitex PRS (Ciba-Geigy Corp.)
Chemical Class	Stilbene derivative
Fluorescence	Reddish-blue
Properties	Very good solubility in water. Good stability to acid and alkali
Applications	Paper, cellulose

C. I. Fluorescent Brightener 137

C. A. Registry Number	Not given in the literature
Commercial Names	Uvitex SIG (Ciba-Geigy Corp.)
Chemical Class	Not given in the literature
Fluorescence	Not given in the literature
Properties	Limited build up on repeated use. Good stability in hopy-chlorite and peroxide liquors
Applications	Cellulose, acetate, nylon

C. I. Fluorescent Brightener 137 is not being manufactured at the present time.

C. I. Fluorescent Brightener 138

C. A. Registry Number	Nwt given in the literature
Commercial Names	Uvitex S3B (Ciba-Geigy Corp.)
Chemical Class	Not given in the literature
Fluorescence	Not given in the literature
Properties	Good fastness to chlorine and good stability to acid
Applications	Cellulose

C. I. Fluorescent Brightener 138 is not being manufactured at the present time.

C. I. Fluorescent Brightener 139

C. A. Registry Number	Not given in the literature
Commercial Names	Uvitex S2R (Ciba-Geigy Corp.)
Chemical Class	Not given in the literature
Flourescence	Not given in the literature
Properties	Considerable build up on repeated use. Good fastness to chlorine and good stability to salts. Withstands normal spray temperatures when incorporated in soap or detergents
Applications	Cellulose

C. I. Fluorescent Brightener 140

C. A. Registry Number	Not given in the literature
Commercial Names	Uvitex SWN (Ciba-Geigy Corp.) Rylux VPA (Chemopol, Czech.)
Chemical Class	Heterocyclic
Fluorescence	Blue
Properties	Good stability to salts. Withstand normal spray temperatures
Applications	Wool, silk, acetate, nylon Soaps, detergents

According to the U. S. Tariff Commission reports, 441 pounds of Fluorescent Brightener 140 were imported into the U. S. in 1972.

C. I. Fluorescent Brightener 141

C. A. Registry Number	Not given in the literature
Commercial Names	Uvitex SWR (Ciba-Geigy Corp.)
Chemical Class	Not given in the literature
Fluorescence	Not given in the literature
Properties	Good stability to salts. Withstand normal spray temperatures
Applications	Wool, silk, acetate, nylon Soaps, detergents

C. I. Fluorescent Brightener 141 is not being manufactured at the present time.

C. I. Fluorescent Brightener 142

C. A. Registry Number	Not given in the literature
Commercial Names	Uvitex VR (Ciba-Geigy Corp.)
Chemical Class	Stilbene derivative
Fluorescence	Blue; reflects green
Properties	Orange-yellow powder Good fastness to washing and stability to dithionite and peroxide
Applications	Cellulose

C. I. Fluorescent Brightener 143

C. A. Registry Number	Not given in the literature
Commercial Names	Supra White BN (Dye-Chem, Ltd., India)
Chemical Class	Stilbene derivative
Fluorescence	Bright blue
Properties	Not given in the literature
Applications	Cellulose, paper

C. I. Fluorescent Brightener 143 is not being manufactured at the present time.

C. I. Fluorescent Brightener 144

C. A. Registry Number	Not given in the literature
Commercial Names	Amar Soap White B, B Conc. (Dye-Chem, Ltd., India)
Chemical Class	Stilbene derivatives
Fluorescence	Bright blue
Properties	Aqueous solutions are unstable to light. Good fastness to chlorine, peroxide and washing
Applications	Cellulose Soaps, detergents

C. I. Fluorescent Brightener 145

C. A. Registry Number	Not given in the literature
Commercial Names	Fluolite SE (Imperial Chemical Industries, Ltd., England); Photine BL, CP (Hickson and Welch, Ltd., England; S. A. Rovira, Spain); Photine CSP (Hickson and Welch, Ltd., England)
Chemical Class	Stilbene derivative
Fluorescence	Blue
Properties	Excellent solubility in cold water. Stability to acids (and resin-catalyst combinations) excellent. Low substantivity. Levelling excellent Fastness: Acid, very good; Alkali, very good; Chlorine, moderate, Dithionite, very good; Light, good; Peroxide very good; Washing, good
Applications	Cellulose

C. I. Fluorescent Brightener 146

C. A. Registry Number	Not given in the literature
Commercial Names	Photine STV (Hickson and Welch, Ltd., England); White STV (Hickson and Dadajee Private, Ltd., India)
Chemical Class	Stilbene derivative
Fluorescence	Bluish-violet
Properties	Not given in the literature
Applications	Not given in the literature

C. I. Fluorescent Brightener 147

C. A. Registry Number	[12224-13-4]
Commercial Names	Amar Supra White BRN (Dye-Chem., Ltd., India)
Chemical Class	Stilbene derivative
Fluorescence	Bright reddish-blue
Properties	Very soluble in slightly warm water Fastness: Chlorine, fair; Light, good; Washing, excellent
Applications	Cellulose, paper

C. I. Fluorescent Brightener 148

C. A. Registry Number	[12224-14-5]
Commercial Names	Blankophor RPA (Farbenfabriken Bayer A. G., Germany)
Chemical Class	Stilbene derivative
Fluorescence	Reddish-blue
Properties	Solutions are not stable to chlorine or chlorite Fastness: Chlorine, good; Light, good; Washing, very good
Applications	Nylon

According to the U. S. Tariff Commission reports, 5,250 pounds of Fluorescent Brightener 148 were imported into the U. S. in 1972.

C. I. Fluorescent Brightener 149

C. A. Registry Number	[12216-91-0]
Commercial Names	Fluolite HWP (Imperial Chemical Industries, Ltd., England)
Chemical Class	Bistriazinylaminostilbene derivative
Fluorescence	Not given in the literature
Properties	Readily soluble in water and very resistant to acid conditions. On paper its fastness to light is only moderate but it is resistant to chlorine, acid and alkali
Applications	Cellulose, paper

C. I. Fluorescent Brightener 149 is not being manufactured at the present time.

C. I. Fluorescent Brightener 150

C. A. Registry Number	[12224-15-6]
Commercial Names	Tinopal IT (Ciba-Geigy Corp.)
Chemical Class	Heterocyclic
Fluorescence	Blue
Properties	Has both reducing and brightening properties. It is extremely sensitive to acid. Fastness to light and washing is good
Applications	Wool, cotton, nylon

C. I. Fluorescent Brightener 151

C. A. Registry Number	[12224-16-7]
Commercial Names	Tinopal ABR (Ciba-Geigy Corp.)
Chemical Class	Triazinylaminostilbene derivative
Fluorescence	Reddish-blue
Properties	Soluble in water, ethylene- and diethyleneglycol and Cellosolve. Insoluble in benzene, chlorobenzene, ether, chloroform and acetone Fastness: Acid, very good; Alkali, very good; Chlorine, good; Dithionite, very good; Light, good; Peroxide, very good
Applications	Cellulose, wool, nylon

C. I. Fluorescent Brightener 152

C. A. Registry Number	Not given in the literature
Commercial Names	Tinopal PG (Ciba-Geigy Corp.)
Chemical Class	Coumarin derivative
Fluorescence	Greenish-blue
Properties	Insoluble in water, soluble in benzene, chlorobenzene, acetone and Cellosolve Fastness: Acid, very gook; Alkali, good; Chlorine, good; Dithionite, very good; Light, very good; Peroxide, good
Applications	Nylon, acetate, polyester

C. I. Fluorescent Brightener 153

C. A. Registry Number	[12224-18-9]
Commercial Names	Tinopal CWS (Ciba-Geigy Corp.); Whitex BWB, Whitex SF (Sumitomo Chemical Co., Ltd., Japan)
Chemical Class	Triazinylaminostilbene derivative
Fluorescence	Blue
Properties	Soluble in water, ethylene and diethylene glycols and Cellosolve. Insoluble in benzene, chlorobenzene, ether, chloroform and acetone Fastness: Acid, poor; Alkali, very good; Chlorine, good; Dithionite, very good; Light, good; Peroxide, very good
Applications	Cellulose, wool, nylon Detergent compositions

C. I. Fluorescent Brightener 154

C. A. Registry Number	[12224-19-0]
Commercial Names	Tinopal UP (Ciba-Geigy Corp.)
Chemical Class	Triazinylaminostilbene derivative
Fluorescence	Blue
Properties	Compatible with cationic softeners. Soluble in water, ethylene and diethyleneglycol and Cellosolve. Insoluble in benzene, chlorobenzene, ether, chloroform and acetone Fastness: Acid, poor; Alkali, very good; Chlorine, good; Dithionite, very good; Light, good; Peroxide, very good
Applications	Cellulose, paper Wool, nylon

C. I. Fluorescent Brightener 155

Colour Index Number	C. I. 45555
C. A. Registry Number	[6250-49-3]
Commercial Names	Not given in the literature
Chemical Class	2,8-dimethylnaphtho[3,2,1-kl]-xanthen-9-ol, acetate
Molecular Formula	$C_{24}H_{18}O_3$
Fluorescence	Green
Properties	Soluble in hydrocarbons, the solutions being stable to heat and light. Also soluble in alcohols, esters, ketones and plasticisers
Applications	Lubricating oils

C. I. Fluorescent Brightener 156

C. A. Registry Number	[12224-20-3]
Commercial Names	Tinopal ethyl (Ciba-Geigy Corp.)
Chemical Class	Coumarin derivative
Fluorescence	Blue
Properties	Insoluble in water, soluble in benzene, chlorobenzene, chloroform, acetone and Cellosolve Fastness: Acid, very good; Alkali, moderate-good; Chlorine, very good; Dithionite, good; Light, very good; Peroxide, moderate-good
Applications	Nylon, acetate, polyesters

C. I. Fluorescent Brightener 157

C. A. Registry Number	[12224-21-4]
Commercial Names	Tinopal LAT (Ciba-Geigy Corp.)
Chemical Class	Coumarin derivative
Fluorescence	Greenish-blue
Properties	Insoluble in water, soluble in benzene, chlorobenzene, chloroform, acetone, Cellosolve and dioxan Stable to chlorite Fastness: Acid, very good; Alkali, good; Chlorine, very good; Dithionite, very good; Light, good; Peroxide, good
Applications	Acetate, triacetate, acrylics

C. I. Fluorescent Brightener 158

C. A. Registry Number	[12224-22-5]
Commercial Names	Calcofluor White Art (American Cyanamid Co.)
Chemical Class	Triazole derivative
Fluorescence	Reddish
Properties	Excellent stability to chlorite and excellent fastness to light
Applications	Acrylics

American Cyanamid Co. reported production and sales of Fluorescent Brightener 158 to the U. S. Tariff Commission in 1972. No production figures are given; they are included in the total brightener production figures.

C. I. Fluorescent Brightener 159

C. A. Registry Number	[12224-23-6]
Commercial Names	Calcofluor White ABT (American Cyanamid Co.)
Chemical Class	Azole derivative
Fluorescence	Blue
Properties	Amber liquid in physical form Specific gravity 1.10 Miscible in water and in acetic acid
Applications	Acrylic fibers

American Cyanamid Co. reported production and sales of Fluorescent Brightener 159 to the U. S. Tariff Commission in 1972. No production figures are given; they are included in the total brightener production figures.

C. I. Fluorescent Brightener 160

C. A. Registry Number	[12224-24-7]
Commercial Names	Calcofluor White NCV (American Cyanamid Co.)
Chemical Class	Benzidine sulfone derivative
Fluorescence	Greenish blue
Properties	Insoluble in water; very soluble in methanol, Methyl Cellosolve, butanol and tetrahydrofurfuryl alcohol; soluble in methyl ethyl ketone and acetone; slightly soluble in toluene and ethyl acetate Fastness to daylight good and to artificial light excellent
Application	Nitrocellulose Cellulose acetate butyrate Chlorinated rubber varnishes

C. I. Fluorescent Brightener 160 is not being manufactured at the present time.

C. I. Fluorescent Brightener 161

C. I. Registry Number	[12224-25-8]
Commercial Names	Calcofluor White 2RP (American Cyanamid Co.)
Chemical Class	Stilbene derivative
Fluorescence	Reddish
Properties	Exhausts slowly, has good fastness to alum and is non-feathering. Fluorescence little affected between pH 4•5-6. Used in paper coating compositions it is satisfactory at pH up to 9
Applications	Paper

C. I. Fluorescent Brightener 161 is not being manufactured at the present time.

C. I. Fluorescent Brightener 162

C. A. Registry Number	[12224-26-9]
Commercial Names	Mikawhite AT (Nippon Kayaku Co., Ltd., Japan; Mitsubishi Chemical Industries, Ltd., Japan)
Chemical Class	Naphthalic acid derivative
Fluorescence	Blue
Properties	Usable at pH 3-11 and stable to chlorite. Excellent fastness to light, washing, perspiration and heat
Applications	Polyester, acrylics, acetate

C. I. Fluorescent Brightener 162:1

C. A. Registry Number	Not given in the literature
Commercial Names	Leukophor EFR (Sandoz, Inc.); Mikawhite ATN, (Nippon Kayaku Co., Ltd., Japan; Mitsubishi Chemical Industries, Ltd., Japan)
Chemical Class	Naphthalic acid derivative
Fluorescence	Not given in the literature
Properties	Not given in the literature
Applications	Polyester-cotton blends

C. I. Fluorescent Brightener 163

C. A. Registry Number	[12224-27-0]

This C. I. generic name is discontinued. The brighteners formerly listed under it now appear under C. I. Fluorescent Brightener 162:1.

C. I. Fluorescent Brightener 164

C. A. Registry Number	[12224-28-1]
Commercial Names	Mikawhite BTN (Nippon Kayaku Co., Ltd., Japan; Mitsubishi Chemical Industries, Ltd., Japan)
Chemical Class	Naphthalic acid derivative
Fluorescence	Blue
Properties	Usable at pH 3-11 and stable to chlorite. Excellent fastness to light, washing, perspiration and heat
Applications	Polyester, acrylics, acetate

C. I. Fluorescent Brightener 165

C. A. Registry Number	Not given in the literature
Commercial Names	Fluolite HM (Imperial Chemical Industries, Ltd., England)
Chemical Class	Stilbene derivative
Fluorescence	Reddish-blue
Properties	Readily soluble in cold water. Stable to acid, alum and rosin. Good build-up
Applications	Paper

C. I. Fluorescent Brightener 166

C. A. Registry Number	[12224-29-2]
Commercial Names	Kayaphor 3BS (Nippon Kayaku Co., Ltd., Japan)
Chemical Class	Stilbene derivative
Fluorescence	Bright greenish blue
Properties	Very good solubility in water. Stripping with chlorite good
Applications	Cellulose, paper Soaps, detergents

C. I. Fluorescent Brightener 167

C. A. Registry Number	[12224-30-5]
Commercial Names	Kayaphor RCS (Nippon Kayaku Co., Ltd., Japan)
Chemical Class	Stilbene derivative
Fluorescence	Bright reddish
Properties	Good solubility in water. Good fastness to chlorine, light, peroxide and washing
Applications	Cellulose, paper

C. I. Fluorescent Brightener 168

C. A. Registry Number	[12224-31-6]
Commercial Names	Kayaphor C (Nippon Kayaku Co., Ltd., Japan)
Chemical Class	Stilbene derivative
Fluorescence	Bright blue
Properties	Very good fastness to chlorine and good fastness to light, peroxide and washing
Applications	Cellulose, paper

C. I. Fluorescent Brightener 169

C. A. Registry Number	[12224-32-7]
Commercial Names	Kayaphor PS (Nippon Kayaku Co., Ltd., Japan)
Chemical Class	Stilbene derivative
Fluorescence	Bright reddish-violet
Properties	Good fastness to chlorine, light, peroxide and washing
Applications	Cellulose, paper

C. I. Fluorescent Brightener 170

C. A. Registry Number	[12236-38-3]
Commercial Names	Mikephor EN (Mitsui Toatsu Chemicals, Inc., Japan)
Chemical Class	Oxazole derivative
Fluorescence	Bluish
Properties	Insoluble in water, soluble in ethanol
Applications	Polyester

C. I. Fluorescent Brightener 171

C. A. Registry Number	[12236-39-4]
Commercial Names	Mikephor EB (Mitsui Toatsu Chemicals, Inc., Japan); Photine EB, EB Liquid (Hickson and Welch Ltd., England)
Chemical Class	Oxazole derivative
Fluorescence	Bluish
Properties	Good fastness to acid and light, very good fastness to alkali, chlorine, dithionite and peroxide
Applications	Nylon, Triacetate, polyester

C. I. Fluorescent Brightener 172

C. A. Registry Number [12224-33-8]

This C. I. generic name is discontinued. The brighteners formerly listed under it now appear under C. I. Fluorescent Brightener 185:1 and 185:2.

C. I. Fluorescent Brightener 173

C. A. Registry Number	[12224-34-9]
Commercial Names	Whitex 10B (Sumitomo Chemical Co., Ltd., Japan)
Chemical Class	Stilbene derivative
Fluorescence	Bright bluish
Properties	Good solubility in water. Good fastness to chlorine, light, peroxide and washing
Applications	Cellulose, paper Soaps, detergents

C. I. Fluorescent Brightener 174

C. A. Registry Number	[12236-40-7]
Commercial Names	Mikephor BE (Mitsui Toatsu Chemicals, Inc., Japan)
Chemical Class	Stilbene derivative
Fluorescence	Greenish-blue
Properties	Readily soluble in cold water. Fastness: Chlorine, poor; washing, excellent
Applications	Cellulose, paper

C. I. Fluorescent Brightener 175

C. A. Registry Number	[12236-41-8]
Commercial Names	Mikephor MX (Mitsui Toatsu Chemicals, Inc., Japan)
Chemical Class	Stilbene derivative
Fluorescence	Bluish
Properties	Water soluble
Applications	Cellulose, paper

C. I. Fluorescent Brightener 176

C. A. Registry Number	[12236-42-9]
Commercial Names	Mikephor RFA (Mitsubi Toatsu Chemicals, Inc., Japan)
Chemical Class	Stilbene derivative
Fluorescence	Reddish blue
Properties	Water soluble
Applications	Cellulose Detergents

C. I. Fluorescent Brightener 177

C. A. Registry Number	[12236-43-0]
Commercial Names	Mikephor RP (Mitsui Toatsu Chemicals, Inc., Japan)
Chemical Class	Stilbene derivative
Fluorescence	Bluish
Properties	Water soluble
Applications	Cellulose

C. I. Fluorescent Brightener 178

C. A. Registry Number	[12236-44-1]
Commercial Names	Mikephor RP (Mitsui Toatsu Chemicals, Inc., Japan)
Chemical Class	Stilbene derivative
Fluorescence	Bluish
Properties	Water soluble
Applications	Wool, nylon

C. I. Fluorescent Brightener 179

C. A. Registry Number	[12224-35-0]
Commercial Names	Fluolite XMF (Imperial Chemical Industries, Ltd., England)
Chemical Class	Triazine derivative
Fluorescence	Bluish
Properties	Stable to peroxide, salt, sodium carbonate, sulphonic acid, anionic and non-ionic surfactants and some cationic surfactants.
Applications	Acetate, triacetate, acrylic, nylon

C. I. Fluorescent Brightener 180

C. A. Registry Number	[12224-36-1]
Commercial Names	Blancol HR (L. B. Holliday and Co., Ltd., England)

This C. I. generic name is discontinued; this brightener is not being manufactured at the present time.

C. I. Fluorescent Brightener 181

C. A. Registry Number	[12224-37-2]
Commercial Names	Uvitex ALN (Ciba-Geigy Corp.)
Chemical Class	Heterocyclic
Fluorescence	Bluish to reddish-blue
Properties	Outstanding fastness to light and washing
Applications	Acrylics

C. I. Fluorescent Brightener 182

C. A. Registry Number	[12224-38-3]
Commercial Names	Uvitex MP (Ciba-Geigy Corp.)
Chemical Class	Triazinylaminostilbene derivative
Fluorescence	Bluish
Properties	Not given in the literature
Applications	Nylon

C. I. Fluorescent Brightener 183

C. A. Registry Number	[12224-39-4]
Commercial Names	Uvitex NB (Ciba-Geigy Corp.)
Chemical Class	Triazinylaminostilbene
Fluorescence	Blue
Properties	Good fastness to light and washing
Applications	Cellulose Nylon

C. I. Fluorescent Brightener 184

C. A. Registry Number	[12224-40-7]
Commercial Names	Uvitex OB (Ciba-Geigy Corp.)
Chemical Class	Heterocyclic
Fluorescence	Bluish
Properties	Not given in the literature
Applications	Acetate, polyvinyl chloride, triacetate

According to the U. S. Tariff Commission reports, 551 pounds of Fluorescent Brightener 184 were imported into the U. S. in 1972.

C. I. Fluorescent Brightener 184:1

C. A. Registry Number	Not given in the literature
Commercial Names	Uvitex OB-C (Ciba-Geigy Corp.)

C. I. Fluorescent Brightener 184:1 is identical to C. I. Fluorescent Brightener 184, but it is extended with chalk to facilitate its dispersion in plastics.

C. I. Fluorescent Brightener 184:2

C. A. Registry Number	Not given in the literature
Commercial Names	Uvitex OB-P (Ciba-Geigy Corp.)

C. I. Fluorescent Brightener 184:2 is chemically identical to C. I. Fluorescent Brightener 184, but contains a softening agent. Its applications are: Plasticised poly(vinyl chloride).

C. I. Fluorescent Brightener 185

C. A. Registry Number	[12224-41-8]
Commercial Names	Uvitex EBF (Ciba-Geigy Corp.)
Chemical Class	Thiophene oxazole derivative
Fluorescence	Bluish
Properties	Outstanding fastness to chlorine, light, and washing on polyester fibers
Applications	Acetate, triacetate, nylon, polyester Polypropylene, poly(vinyl chloride)

C. I. Fluorescent Brightener 185:1

C. A. Registry Number	Not given in the literature
Commercial Names	Whitex SNK (Sumitomo Chemical Co., Ltd., Japan)
Chemical Class	Thiophene oxazole derivative
Fluorescence	Bright bluish
Properties	Stable in chlorite bleaching baths and peracetic acid Fastness: (polyester or polypropylene), light, excellent; organic solvents, very good; washing, excellent
Applications	Polypropylene Polyester, Polyvinyl, nylon

C. I. Fluorescent Brightener 185:1 is not being manufactured at the present time.

C. I. Fluorescent Brightener 185:2

C. A. Registry Number	Not given in the literature
Commercial Names	Whitex NKR (Sumitomo Chemical Co., Ltd., Japan)
Chemical Class	Thiophene oxazole derivative
Fluorescence	Bright reddish
Properties	Stable in chlorite bleaching baths and peracetic acid Fastness: (polyester or polypropylene), light, excellent; organic solvents, very good; washing, excellent
Applications	Polypropylene Polyester, Polyvinyl, nylon

C. I. Fluorescent Brightener 186

C. A. Registry Number	[12224-42-9]
Commercial Names	Uvitex SFC (Ciba-Geigy Corp.)
Chemical Class	Stilbene derivative
Fluorescence	Blue
Properties	Excellent fastness to acid and to perspiration
Applications	Soaps, detergents

C. I. Fluorescent Brightener 187

C. A. Registry Number	[12224-43-0]
Commercial Names	Uvitex SFC (Ciba-Geigy Corp.)
Chemical Class	Stilbene derivative
Fluorescence	Bluish
Properties	Not given in the literature
Applications	Paper

C. I. Fluorescent Brightener 188

C. A. Registry Number	[12224-44-1]
Commercial Names	Uvitex SBRN (Ciba-Geigy Corp.)
Chemical Class	Stilbene derivative
Fluorescence	Bluish
Properties	Not given in the literature
Applications	Cellulose, nylon Detergents

C. I. Fluorescent Brightener 189

C. A. Registry Number	[12224-45-2]
Commercial Names	Uvitex SK (Ciba-Geigy Corp.)
Chemical Class	Heterocyclic
Fluorescence	Bluish
Properties	Stable in washing liquors containing hypochlorite or chloroisocyanuric acid. Excellent fastness (on fibre) to acids, chlorine, light and washing
Applications	Detergents

C. I. Fluorescent Brightener 190

C. A. Registry Number	[12224-46-3]
Commercial Names	Uvitex SOF (Ciba-Geigy Corp.)
Chemical Class	Heterocyclic
Fluorescence	Bluish
Properties	Stable in washing liquors containing hypochlorite or chloroisocyanuric acid. Excellent fastness (on fibre) to acids, chlorine, light and washing
Applications	Detergents

C. I. Fluorescent Brightener 191

C. A. Registry Number	[12270-53-0]
Commercial Names	Blankophor CL (Farbenfabriken Bayer A. G., Germany)
Chemical Class	Stilbene derivative
Fluorescence	Reddish-violet
Properties	Anionic. Stability (in soln), acid, very good; alkali, good; cationic softeners, pptd; chlorite, very good; dithionite, very good; heat, very good; hard water, pptd; hypochlorite, good at pH 10-12; peroxide, very good
Applications	Cellulose, nylon

According to the U. S. Tariff Commission Reports, 77,975 pounds of Fluorescent Brightener 191 were imported into the U. S. in 1972.

C. I. Fluorescent Brightener 192

C. A. Registry Number	[12270-54-1]
Commercial Names	Blankophor PSL (Farbenfabriken Bayer A. G., Germany)
Chemical Class	Stilbene derivative
Fluorescence	White
Properties	Cationic. Stable in solution to acid and dithionite, not stable to chlorine or chlorite
Applications	Acrylic, wool, silk

C. I. Fluorescent Brightener 193

C. A. Registry Number	[12270-55-2]
Commercial Names	Blankophor PSL (Farbenfabriken Bayer A. G., Germany)
Chemical Class	4,4'-Diaminostilbene-2,2'-disulfonic acid derivative
Fluorescence	Slightly reddish
Properties	Good solubility in water, extremely good resistance to acid, little substantive to cellulose
Applications	Paper

C. I. Fluorescent Brightener 194

C. A. Registry Number	[12270-56-3]
Commercial Names	Glowhite BBN (Amar Dye-Chem., Ltd., India)
Chemical Class	Stilbene derivative
Fluorescence	Bright blue
Properties	Very soluble in water. Fastness to light good and to chlorine and washing very good
Applications	Cellulose, paper

C. I. Fluorescent Brightener 195

C. A. Registry Number	[12270-57-4]
Commercial Names	Glowhite BRN (Amar Dye-Chem., Ltd., India)
Chemical Class	Stilbene derivative
Fluorescence	Bright reddish blue
Properties	Good solubility in water. Stable to acids and reducing agents Fastness: Chlorine, moderate; Light, good; Washing, very good
Applications	Cellulose

C. I. Fluorescent Brightener 196

C. A. Registry Number	[12270-58-5]
Commercial Names	Glowhite NAN (Amar Dye-Chem., Ltd., India)
Chemical Class	Coumarin derivative
Fluorescence	Reddish-violet
Properties	Readily soluble in cold water Fastness: Light, moderate; Washing, moderate to good
Applications	Protein fibers, acetate, nylon

Since C. A. Registry Numbers are not available for brighteners beyond C. I. Fluorescent Brightener 196, this item will be deleted from the following tables (C. I. Fluorescent Brightener 231 is an exception).

C. I. Fluorescent Brightener 197

Commercial Names	Ultraphor AL (Badische Anilin & Soda Fabrik A. G., Germany)
Chemical Class	Azacyanine derivative
Fluorescence	Reddish-blue
Properties	Cationic. Good solubility. Stable to cationic softeners and peroxide, not stable to reducing agent. Can be used in chlorite bleaching baths
Applications	Acrylic, triacetate, acetate

C. I. Fluorescent Brightener 197 is not being manufactured at the present time.

C. I. Fluorescent Brightener 198

Commercial Names	Pananil Brilliant White G (Badische Anilin & Soda Fabrik A. G., Germany)
Chemical Class	Stilbene derivative
Fluorescence	Greenish-blue
Properties	Non-ionic. Good solubility. Stable to cationic softeners. Can be used in chlorite, peroxide and reduction bleaching baths
Applications	Polyester, acetate, nylon, triacetate

C. I. Fluorescent Brightener 199

Commercial Names	Palanil Brilliant White R (Badische Anilin & Soda Fabrik, A. G., Germany)
Chemical Class	Stilbene derivative
Fluorescence	Reddish-blue
Properties	Non-ionic. Good solubility. Stable to cationic softeners. Can be used in chlorite, peroxide and reduction bleaching baths
Applications	Polyester, acetate, nylon, triacetate

C. I. Fluorescent Brightener 200

Commercial Names	Blankophor BK (Farbenfabriken Bayer A. G., Germany)
Chemical Class	Stilbene derivative
Fluorescence	Bluish-violet
Properties	Anionic. Sensitive to hard water and cationic softeners. Stable to acids, alkalies, dithionite and heat
Applications	Cotton and Polyester-cotton blends

According to the U. S. Tariff Commission Reports, 46, 250 pounds of Fluorescent Brightener 200 were imported into the U. S. in 1972.

C. I. Fluorescent Brightener 201

Commercial Names	Blankophor ACB (Farbenfabriken Bayer A. G., Germany)
Chemical Class	Stilbene derivative
Fluorescence	Bluish-violet
Properties	Cationic. Good solubility in water. Stable to cationic softeners and dithionite
Applications	Acrylics

C. I. Fluorescent Brightener 202

Commercial Names	Blankophor ACR (Farbenfabriken Bayer, A. G., Germany)
Chemical Class	Nitrogen heterocycle
Properties	Cationic. Good solubility in water. Unstable in neutral or alkaline baths
Applications	Acrylics

C. I. Fluorescent Brightener 203

Commercial Names	Blankophor KL (Farbenfabriken Bayer A. G., Germany)
Chemical Class	Coumarin derivative
Fluorescence	Bluish
Properties	Insoluble in water, soluble in many solvents. Excellent resistance to heat, acid and alkali, n.p. 70°C
Applications	Plastics, resins, plasticizers, lacquers

C. I. Fluorescent Brightener 204

Commercial Names	Blankophor RA (Farbenfabriken Bayer A. G., Germany)
Chemical Class	Stilbene derivative
Fluorescence	Bluish-violet
Properties	Anionic. High substantivity, not dischargeable and difficult to strip. Not stable in solution to chlorine and chlorite bleaching baths
Applications	Cellulose, Polyester-cotton blends, Nylon-cotton blends

C. I. Fluorescent Brightener 205

Commercial Names	Blankophor RKH (Farbenfabriken Bayer A. G., Germany)
Chemical Class	Stilbene derivative
Fluorescence	White
Properties	Anionic. Good solubility in boiling water, good dispersibility in cold water. Very good resistance to spray drying, alkalis and peroxides. Good substantivity. In solution unstable to chlorine but has good fastness on the fibre
Applications	Cellulose

According to the U. S. Tariff Commission Reports, 490,665 pounds of Fluorescent Brightener 205 were imported into the U. S. in 1972.

C. I. Fluorescent Brightener 206

Commercial Names	Blankophor FBO (Farbenfabriken Bayer A. G., Germany)
Chemical Class	Nitrogen heterocycle
Fluorescence	Reddish-blue
Properties	Non-ionic. Insoluble in water, readily dispersible in water in presence of detergents. Very good stability to spray drying, alkalis and peroxides. In solution unstable to chlorine
Applications	Acetate, nylon, triacetate

C. I. Fluorescent Brightener 207

Commercial Names	Photine VN (Hickson and Welch, Ltd., England)
Chemical Class	Stilbene derivative
Fluorescence	Bluish-violet
Properties	Water soluble. Good substantivity. Fastness to acid, alkali, chlorine and light good and to dithionite and peroxide very good
Applications	Nylon

C. I. Fluorescent Brightener 208

Commercial Names	Photine LTD (Hickson and Welch, Ltd., England)
Chemical Class	Stilbene derivative
Fluorescence	Reddish-blue
Properties	Water soluble. Good substantivity. Fastness to acid and light good, to alkali, chlorine, dithionite and peroxide very good
Applications	Cellulose Soaps, detergents

C. I. Fluorescent Brightener 209

Commercial Names	Photine PT New, Photine Paper-white P (Hickson and Welch, Ltd., England; S. A. Rovira, Spain)
Chemical Class	Stilbene derivative
Fluorescence	Reddish-blue
Properties	Readily soluble in water. Stable to high concentrations of alum. Good substantivity. Fastness to chlorine and light good, to acid, alkali, dithionite and peroxide very good
Applications	Paper

C. I. Fluorescent Brightener 210

Commercial Names	Photine BPM (Hickson and Welch, Ltd., England)
Chemical Class	Stilbene derivative
Fluorescence	Blue
Properties	Readily soluble in water. Good substantivity. Fastness to chlorine and light good, to acid, alkali, dithionite and peroxide very good
Applications	Paper

C. I. Fluorescent Brightener 211

Commercial Names	Photine BTM (Hickson and Welch, Ltd., England)
Chemical Class	Stilbene derivative
Fluorescence	Blue
Properties	Readily soluble in water. Moderate substantivity. Sensitive to electrolytes. Fastness to chlorine and light good, to acid, alkali, dithionite and peroxide very good
Applications	Cellulose Nylon

C. I. Fluorescent Brightener 212

Commercial Names	Photine CXT (Hickson & Welch, Ltd., England)
Chemical Class	Stilbene derivative
Fluorescence	Reddish-blue
Properties	Dispersible in cold water, soluble in hot water. High substantivity. Fastness to acid poor, to light good and to alkali, chlorine, dithionite and peroxide very good
Applications	Cellulose Nylon, protein fibers

C. I. Fluorescent Brightener 213

Commercial Names	Photine HV, HVS, VHP (Hickson and Welch, Ltd., England; S. A. Rovira, Spain; Hickson and Dadajee Private Ltd., India)
Chemical Class	Stilbene derivative
Fluorescence	Reddish-blue
Properties	Readily soluble in water. Good substantivity. Fastness to chlorine and light good, to acid, alkali, dithionite and peroxide very good
Applications	Cellulose, paper Nylon, protein fibers

C. I. Fluorescent Brightener 214

Commercial Names	Photine HVD, RD245D (Hickson and Welch, Ltd., England; S. A. Rovira, Spain; Hickson and Dadajee Private Ltd., India)
Chemical Class	Stilbene derivative
Fluorescence	Reddish-blue
Properties	Readily soluble in water. Good Substantivity. Fastness to chlorine and light good, to acid, alkali, dithionite and peroxide very good
Applications	Cellulose Soaps, detergents

C. I. Fluorescent Brightener 215

Commercial Names	Photine LV (Hickson and Welch, Ltd., England)
Chemical Class	Stilbene derivative
Fluorescence	Reddish-blue
Properties	Soluble in water. Medium substantivity. Fastness to alkali, chlorine and light good, to acid and dithionite very good
Applications	Cellulose Nylon

C. I. Fluorescent Brightener 216

Commercial Names	Kayaphor BR (Nippon Kayaku Co., Ltd., Japan)
Chemical Class	Bistriazinylaminostilbene derivative
Fluorescence	Reddish-blue
Properties	Very good solubility in water. Fastness to dithionite and light good, to acid, alkali, chlorine and peroxide very good
Applications	Cellulose Nylon, protein fibers

C. I. Fluorescent Brightener 217

Commercial Names	Kayaphor W (Nippon Kayaku Co., Ltd., Japan); Whitex BRF (Sumitomo Chemical Co., Ltd., Japan)
Chemical Class	Pyrazoline derivative
Fluorescence	Reddish-blue
Properties	Good solubility in water. Fastness to alkali and light good, to acid, dithionite and peroxide very good
Applications	Wool, nylon

C. I. Fluorescent Brightener 218

Commercial Names	Kayaphor N (Nippon Kayaku Co., Ltd., Japan)
Chemical Class	Bistriazinylaminostilbene
Fluorescence	Reddish-blue
Properties	Good solubility in water. Fastness to light good, to acid, alkali, chlorine, dithionite and peroxide very good
Applications	Cellulose Wool, nylon

C. I. Fluorescent Brightener 219

Commercial Names	White WP (Sumitomo Chemical Co., Ltd., Japan)
Chemical Class	Oxazole derivative
Fluorescence	Reddish-blue
Properties	Insoluble in water but readily dispersed in cold water. Fastness to acid, alkali, chlorine, dithionite, light and peroxide very good
Applications	Polypropylene Nylon, acetate, poly(vinyl chloride)

C. I. Fluorescent Brightener 219:1

Commercial Names	Kayaphor OLN (Nippon Kayaku Co., Ltd., Japan)
Chemical Class	Oxazole derivative
Fluorescence	Neutral
Properties	Readily dispersible in water. Fastness to chlorine, sublimation and washing good and to light excellent
Applications	Polypropylene Polyester, nylon, poly(vinyl chloride)

C. I. Fluorescent Brightener 219:2

Commercial Names	Kayaphor OLR (Nippon Kayaku Co., Ltd., Japan)
Chemical Class	Oxazole derivative
Fluorescence	Slightly reddish
Properties	Readily dispersible in water. Fastness to chlorine, sublimation and washing good and to light excellent
Applications	Polypropylene Polyester, nylon, poly(vinyl chloride)

C. I. Fluorescent Brightener 220

Commercial Names	Fluolite PS Liquid (Imperial Chemical Industries, Ltd., England)
Chemical Class	Stilbene derivative
Fluorescence	Bluish
Properties	Miscible with cold soft water in all proportions. Stable to alum and strong and weak acids and alkalis
Applications	Paper

C. I. Fluorescent Brightener 221

This C. I. generic name is discontinued. The brighteners formerly listed under it now appear under C. I. Fluorescent Brightener 146.

C. I. Fluorescent Brightener 222

Commercial Names	Photine SPC (Hickson and Welch, Ltd., England); White SPC (Hickson and Dadajee Private Ltd., India)
Chemical Class	Stilbene derivative
Fluorescence	Bluish-red
Properties	Soluble in water. Fastness to chlorine poor, to acid, alkali, light and peroxide good and to dithionite very good
Applications	Cellulose, paper

C. I. Fluorescent Brightener 223

Commercial Names	Kayaphor CR (Nippon Kayaku Co., Ltd., Japan)
Chemical Class	Bistriazinylaminostilbene derivative
Fluorescence	Bright reddish blue
Properties	Good solubility in water. Fastness to acid, dithionite and light good, to alkali, chlorine and peroxide very good
Applications	Cellulose, paper Nylon

C. I. Fluorescent Brightener 224

Commercial Names	Kayaphor HAS (Nippon Kayaku Co., Ltd., Japan)
Chemical Class	Bistriazinylaminostilbene derivative
Fluorescence	Neutral
Properties	Good solubility in water. Fastness to light good and to acid, alkali, chlorine, dithionite and peroxide very good
Applications	Cellulose, paper Wool, nylon Poly(vinyl alcohol)

C. I. Fluorescent Brightener 225

Commercial Names	Kayaphor LSK (Nippon Kayaku Co., Ltd., Japan); Whitex SKC (Sumitomo Chemical Co., Ltd., Japan)
Chemical Class	Bistriazinylaminostilbene derivative
Fluorescence	Neutral
Properties	Slightly soluble in water. Fastness to dithionite, light and peroxide good, to alkali and chlorine very good
Applications	Cellulose Nylon Soaps, detergents

C. I. Fluorescent Brightener 226

Commercial Names	Mikawhite ACR (Nippon Kayaku Co., Ltd., Japan)
Chemical Class	Acenaphthene derivative
Fluorescence	Neutral
Properties	Readily soluble in cold water. Very good fastness to acid, alkali, chlorine, dithionite, light and peroxide
Applications	Acrylics

C. I. Fluorescent Brightener 227

Commercial Names	Mikawhite STN (Nippon Kayaku Co., Ltd., Japan)
Chemical Class	Acenaphthene derivative
Fluorescence	Bluish
Properties	Insoluble but readily dispersible in water. Very good fastness to acid, alkali, chlorine, dithionite, light and peroxide
Applications	Polyester, acrylic, acetate, nylon

C. I. Fluorescent Brightener 228

Commercial Names	Photine TCA (Hickson and Welch, Ltd., England)
Chemical Class	Heterocyclic
Fluorescence	Bluish-violet
Properties	Insoluble in water. High substantivity. Fastness to chlorine poor, to acid, dithionite and peroxide good, to light very good and alkali excellent
Applications	Acetate, triacetate, acrylic, nylon

C. I. Fluorescent Brightener 229

Commercial Names	Blankophor EBL (Farbenfabriken Bayer A. G., Germany)
Chemical Class	Coumarin derivative
Fluorescence	Neutral
Properties	Non-ionic. Stable in solution and in the fibre to acid, alkali, chlorite, hard water, hypochlorite and reducing agents
Applications	Polyester, polyester-cotton blends

According to U. S. Tariff Commission Reports, 77,160 pounds of Fluorescent Brightener 229 were imported into the U. S. in 1972.

C. I. Fluorescent Brightener 230

Commercial Names	Leukophor AP (Sandoz Colors and Chemicals)
Chemical Class	Bistriazinylaminostilbene derivative
Fluorescence	Blue
Properties	Not stable to acids and electrolytes
Applications	Cotton Paper

C. I. Fluorescent Brightener 231

C. A. Registry Number	[12676-64-1]
Commercial Names	Leukophor C (Sandoz Colors and Chemicals)
Chemical Class	Bistriazinylaminostilbene derivative
Fluorescence	Blue
Properties	Excellent solubility in water. Stable to acid and alkali. Heavy metal salts lessen the fluorescence
Applications	Cellulose, paper

C. I. Fluorescent Brightener 232

Commercial Names	Leukophor CK (Sandoz Colors and Chemicals)
Chemical Class	Bistriazinylaminostilbene derivative
Fluorescence	Blue
Properties	Stable to acid and alkali. Heavy metal salts lessen the fluorescence
Applications	Paper

C. I. Fluorescent Brightener 233

Commercial Names	Leukophor DT (Sandoz Colors and Chemicals)
Chemical Class	Bistriazinylaminostilbene derivative
Fluorescence	Brilliant blue
Properties	Solubility in water at 100°C 10 mg/1. Stable to perborate and alkalis. Looses its fluorescence in warm liquors containing hypochlorite but on the fibre is negligibly affected by chlorine
Applications	Washing powders for cellulose and nylon textiles

C. I. Fluorescent Brightener 234

Commercial Names	Leukophor PAF (Sandoz Colors and Chemicals)
Chemical Class	Bistriazinylaminostilbene derivative
Fluorescence	Reddish-blue
Properties	Soluble in hot water. Stable to acids and alkalis, not stable to chlorine
Applications	Nylon, nylon-wool blends, nylon-cellulose blends, wool

C. I. Fluorescent Brightener 235

Commercial Names	Leukophor SPA (Sandoz Colors and Chemicals)
Chemical Class	Bistriazinylaminostilbene derivative
Fluorescence	Very brilliant blue
Properties	Stable to acids and alkalis but heavy metal salts reduce the fluorescence
Applications	Paper

C. I. Fluorescent Brightener 236

Commercial Names	Leukopur EGM (Sandoz Colors and Chemicals)
Chemical Class	Coumarin derivative
Fluorescence	Blue
Properties	Soluble in hot organic solvents. Stable to acids and alkalis
Applications	Polyester

C. I. Fluorescent Brightener 237

This C. I. generic name is discontinued. The brighteners formerly listed under it now appear under C. I. Fluorescent Brightener 222.

C. I. Fluorescent Brightener 238

Commercial Names	Lyrcamine White NL (Compagnie Francaise des Matieres Colorantes, France)
Chemical Class	Naphthalimide derivative
Fluorescence	Violet
Properties	Cationic in nature. Soluble in strong sulfuric acid
Applications	Acrylics

According to the U. S. Tariff Commission Reports, 1,587 pounds of Fluorescent Brightener 238 were imported into the U. S. in 1972.

C. I. Fluorescent Brightener 239

Commercial Names	Kayaphor NL (Nippon Kayaku Co., Ltd., Japan)
Chemical Class	Bistriazinylaminostilbene derivative
Fluorescence	Bluish-violet
Properties	Readily soluble in cold water. Fastness to chlorine moderate, to alkalis and light good, to acid, dithionite and peroxide very good
Applications	Cellulose, paper Protein fibers, nylon

C. I. Fluorescent Brightener 240

Commercial Names	Kayaphor SFN (Nippon Kayaku Co., Ltd., Japan)
Chemical Class	Bistriazinylaminostilbene derivative
Fluorescence	Bluish-violet
Properties	Very good solubility in hot water. Good compatibility with cationic compounds in detergent compositions
Applications	Paper, cellulose Wool, nylon

C. I. Fluorescent Brightener 241

Commercial Names	Kayaphor CPS Conc. (Nippon Kayaku Co., Ltd., Japan)
Chemical Class	Bistriazinylaminostilbene derivative
Fluorescence	Bluish-violet
Properties	Solubility in water 10 g/l at 75°C. Exhausts well on cellulose from cold solution. Fastness to chlorine moderate, to light good and to acid, alkali, dithionite and peroxide very good
Applications	Paper Detergents for wool, nylon, and cellulose

C. I. Fluorescent Brightener 242

Commercial Names	Kayaphor PBN (Nippon Kayaku Co., Ltd., Japan)
Chemical Class	Bistriazinylaminostilbene derivative
Fluorescence	Bluish-violet
Properties	Fastness to chlorine moderate, to alkali and light good and to acid, dithionite and peroxide very good
Applications	Cellulose, paper Wool, nylon

C. I. Fluorescent Brightener 243

Colour Index Number	C. I. 40619
Commercial Names	Heliofor 2BC (CIECH, Poland)
Chemical Class	4,4'-Bis[(4-amino-6-hydroxy-s-triazin-2-yl)amino]-2,2'-stilbenedisulfonic acid, disodium salt
Molecular Formula	$C_{20}H_{18}N_{10}O_8S_2 \cdot 2Na$
Fluorescence	Bluish
Properties	Soluble in water
Applications	Cellulose

C. I. Fluorescent Brightener 244

Commercial Names	Heliofor 3BC (CIECH, Poland)
Chemical Class	Stilbene derivative
Fluorescence	Bluish
Properties	Slightly soluble in water
Applications	Cellulose

C. I. Fluorescent Brightener 245

Colour Index Number	C. I. 40615
Commercial Names	Heliofor ZSP (CIECH, Poland)
Chemical Class	4,4'-Bis[(4-chloro-6-amino-s-triazin-2-yl)amino]-2,2'-stilbenedisulfonic acid, disodium salt
Molecular Formula	$C_{20}H_{14}Cl_2N_{10}O_6S_2 \cdot 2Na$
Fluorescence	Greenish-blue
Properties	Slightly soluble in water. Fast to thermofixation
Applications	Nylon

C. I. Fluorescent Brightener 246

Commercial Names	Heliofor SPC (CIECH, Poland)
Chemical Class	Stilbene derivative
Fluorescence	Bluish
Properties	Soluble in water. Fast to thermofixation
Applications	Cellulose Nylon

C. I. Fluorescent Brightener 247

Commercial Names	Heliofor VM (CIECH, Poland)
Chemical Class	Stilbene derivative
Fluorescence	Bluish
Properties	Does not affect the viscosity, stability or the filtration and extrusion properties of viscose solution
Applications	Viscose

C. I. Fluorescent Brightener 248

Commercial Names	Heliofor SPM (CIECH, Poland)
Chemical Class	Stilbene derivative
Fluorescence	Bluish
Properties	Soluble in water. Fast to thermofixation
Applications	Acrylic, nylon

C. I. Fluorescent Brightener 249

Commercial Names	Heliofor V, VP (CIECH, Poland)
Chemical Class	Stilbene derivative
Fluorescence	Reddish
Properties	Soluble in water
Applications	Cellulose, paper

C. I. Fluorescent Brightener 249:1

Commercial Names	Not given in the literature
Chemical Class	Stilbene derivative
Fluorescence	Reddish
Properties	Not given in the literature
Applications	Paper

C. I. Fluorescent Brightener 250

Commercial Names	Heliofor BDC (CIECH, Poland)
Chemical Class	Stilbene derivative
Fluorescence	Bluish
Properties	Excellent fastness to alkali and perborates
Applications	Cellulose

C. I. Fluorescent Brightener 251

Commercial Names	Tinopal 2BT (Ciba-Geigy Corp.)
Chemical Class	Stilbyl-s-triazine derivative
Fluorescence	Bluish
Properties	Not given in the literature
Applications	Cellulose

According to the U. S. Tariff Commission Reports, 220 pounds of Fluorescent Brightener 251 were imported into the U. S. in 1972.

C. I. Fluorescent Brightener 252

Commercial Names	Tinopal BHT (Ciba-Geigy Corp.)
Chemical Class	Stibyl-s-triazine derivative
Fluorescence	Bluish
Properties	Not given in the literature
Applications	Cellulose

C. I. Fluorescent Brightener 253

Commercial Names	Tinopal WHN (Ciba-Geigy Corp.)
Chemical Class	Stibyl-s-triazine derivative
Fluorescence	Bluish
Properties	Not given in the literature
Applications	Polyacrylonitrile Wool

C. I. Fluorescent Brightener 254

Commercial Names	Tinopal ERT (Ciba-Geigy Corp.)
Chemical Class	Coumarinyl-pyrazole derivative
Fluorescence	Reddish
Properties	Not given in the literature
Applications	Polyester

According to the U. S. Tariff Commission Reports, 1,102 pounds of Fluorescent Brightener 254 were imported into the U. S. in 1972.

C. I. Fluorescent Brightener 255

Commercial Names	Tinopal NTH (Ciba-Geigy Corp.)
Chemical Class	Stilbyl-s-triazine derivative
Fluorescence	Slightly bluish
Properties	Not given in the literature
Applications	Not given in the literature

C. I. Fluorescent Brightener 256

Commercial Names	Tinopal 2RT (Ciba-Geigy Corp.)
Chemical Class	Stilbyl-s-triazine derivative
Fluorescence	Reddish
Properties	Not given in the literature
Applications	Not given in the literature

C. I. Fluorescent Brightener 257

Commercial Names	Blankophor ANR (Farbenfabriken Bayer A. G., Germany)
Chemical Class	Coumarin derivative
Fluorescence	Reddish
Properties	In solution is not resistant to hypochlorite, peroxide and alkalis but on the fibre has very good resistance to them. Very good resistance both in soln and on the fibre to dithionite, acids and hard water
Applications	Acrylics

According to the U. S. Tariff Commission Reports, 1,050 pounds of Fluorescent Brightener were imported into the U. S. in 1972.

C. I. Fluorescent Brightener 258

Commercial Names	Whitex SNP (Sumitomo Chemical Co., Ltd., Japan)
Chemical Class	Oxazole derivative
Fluorescence	Bluish violet
Properties	Insoluble in water
Applications	Polyolefin, polyester

C. I. Fluorescent Brightener 259

Commercial Names	Whitex AC (Sumitomo Chemical Co., Ltd., Japan)
Chemical Class	Oxazole derivative
Fluorescence	Bluish
Properties	Soluble in water
Applications	Acrylics

C. I. Fluorescent Brightener 260

Commercial Names	Whitex SA (Sumitomo Chemical Co., Ltd., Japan)
Chemical Class	Stilbene derivative
Fluorescence	Bluish
Properties	Fastness: Alkali, Chlorine, Dithionite, Peroxide and Washing, very good; Light, good
Applications	Cellulose Soaps and detergents

C. I. Fluorescent Brightener 261

Commercial Names	Whitex SEC (Sumitomo Chemical Co., Ltd., Japan)
Chemical Class	Stilbene derivative
Fluorescence	Bluish
Properties	Fastness: Acid, Chlorine, and Light, good; Alkali, Dithionite, Peroxide and Washing, very good
Applications	Cellulose Soaps and detergents

C. I. Fluorescent Brightener 265

According to the U. S. Tariff Commission Reports, 450 pounds of Fluorescent Brightener 265 were imported into the U. S. in 1972.

No further correlations could be established between C. I. Fluorescent Brightener numbers and miscellaneous data on the brighteners, because of a lack of indicative information.

Following are data on some optical brighteners for which no C. I. Fluorescent Brightener numbers were obtained.

Hiltamine Arctic Paper White DSA (Hilton-Davis Division of Sterling Drug Co.)

Chemical Class	Triazinylstilbene derivative
Properties	Liquid in form; pH 9.0-10.0 Anionic in nature Miscible with water in all proportions
Applications	Paper

Hiltamine Arctic Paper White HMS (Hilton-Davis Division of Sterling Drug Co.)

Chemical Class	Triazinylstilbene derivative
Properties	Liquid in form; pH 8.6-9.8 Anionic in nature Miscible with water in all proportions
Applications	Paper

Hiltamine Arctic Paper White LG (Hilton-Davis Division of Sterling Drug Co.)

Chemical Class	Triazinylstilbene derivative
Properties	Liquid in form; pH 6.8-7.8 Anionic in nature Miscible with water in all proportions
Applications	Paper

Hiltamine Arctic White GT (Hilton-Davis Division of Sterling Drug Co.)

Chemical Class	Triazinylstilbene derivative
Properties	Liquid in form; pH 8.8-9.8 Anionic in nature Miscible with water in all proportions
Applications	Textiles; resin finishes

Hiltamine Arctic White SC (Hilton-Davis Division of Sterling Drug Co.)

Chemical Class	Triazinylstilbene derivative
Properties	Liquid in form; pH 8.2-9.2 Anionic in nature Miscible with water in all proportions
Applications	Textiles Liquid detergents, laundry softeners

Hiltamine Arctic White CC (Hilton-Davis Division of Sterling Drug Co.)

Chemical Class	Triazinylstilbene derivative
Properties	Liquid in form; pH 9.5-10.5 Anionic in nature Compatible with cationic, anionic, and nonionic softeners Miscible with water in all proportions
Applications	Textiles Fabric softeners

Hiltamine Arctic White TX (Hilton-Davis Division of Sterling Drug Co.)

Chemical Class	Triazinylstilbene derivative
Properties	Liquid in form; pH 8.5-10.5 Anionic in nature Compatible with cationic, anionic, and nonionic in nature Miscible with water in all proportions
Applications	Textiles Fabric softeners

Hiltamine Arctic White MSO (Hilton-Davis Division of Sterling Drug Co.)

Chemical Class	Triazinylstilbene derivative
Properties	Powder in form Anionic in nature Insoluble in aqueous acidic solutions Slightly soluble in aqueous alkali
Applications	Cold water, all-temperature, low-phosphate, and no-phosphate laundry formulations

Hiltamine Arctic White CWD (Hilton-Davis Division of Sterling Drug Co.)

Chemical Class	Triazinylstilbene derivative
Properties	Powder in form Anionic in nature Low solubility at acidic pH levels
Applications	Cold water laundry formulations Detergents Fabric Softeners

Hiltamine Arctic White SOL (Hilton-Davis Division of Sterling Drug Co.)

Chemical Class	Coumarin derivative
Properties	Powder in form Nonionic in nature Water insoluble Soluble in alcohol, benzene, ketones, detergents, and resins
Applications	Fine fabric detergent formulations Textiles; polyamides

Safratone White WNOA (Hilton-Davis Division of Sterling Drug Co.)

Chemical Class	Coumarin derivative
Properties	Powder in form Nonionic in nature Readily dissolves in warm water
Applications	Detergent formulations Textiles; polyamides, acetate, triacetate

Advabrite BMV (Cincinnati Milacron Chemicals Inc.)

Chemical Name	7-Hydroxy-4-Methylcoumarin
Molecular Formula	$C_{10}H_8O_3$
Properties	Light tan powder M.P. 184-194°C Outdoor durability Exhibits strong blue fluorescence under black light
Applications	Pigmented coatings Solvent and water-based coatings

Advabrite MDAC (Cincinnati Milacron Chemicals Inc.)

Chemical Name	7-(Diethylamino)-4-Methylcoumarin
Molecular Formula	$C_{14}H_{17}NO_2$
Properties	White to light tan powder M.P. 68-73°C Excellent heat stability and outdoor durability Exhibits strong blue fluorescence under black light
Applications	Pigmented coatings Solvent and water-based coatings

Advabrite M-10 (Cincinnati Milacron Chemicals, Inc.)

Properties	Clear liquid Safe for skin contact, but not recommended for food packaging
Application	Plastic

Calcofluor White A2RT Solution (American Cyanamid Co.)

Properties	Reddish-blue fluorescence Excellent fastness to light and stability to chlorine bleach Amber liquid Specific gravity 1.09-1.10 Miscible in water and acetic acid
Application	Acrylic fibers

Calcofluor White CBP Solution (American Cyanamid Co.)

Properties	Characteristics of a low substantive direct dye Pale amber liquid pH 9.8 Slight odor of ammonia Anionic in reaction Soluble in water Specific gravity 1.11
Application	Paper

Calcofluor White LPH Solution (American Cyanamid Co.)

Properties	Amber solution Negligible odor pH 7.5-8.0 Specific gravity 1.2
Application	Paper

Aclarat 8678 (Sandoz Colors and Chemicals)

Properties	Powder in form Insoluble in water Soluble in equal weight of sulfuric or hydrochloric acid Soluble in nonionic, anionic, and cationic surfactants Soluble in nearly all common organic solvents Compatible with acids, reducing agents, oxidizing agents, anionics, cationics, and non-ionics
Applications	Nylon, acetate, wool, silk Shampoo additive Fabric softeners Soaps
Suggested application	Brightening agent in hydrogen peroxide hair bleaches

Sandoz TH-40 (Sandoz Colors and Chemicals)

Properties	Brown liquid Anionic in nature Substantive to cotton, rayon, and nylon Compatible with anionic and nonionic compounds, thermo-setting resins, alkalies, slightly acidic media, oxygen bleaches
Application	Cellulosic materials

Leucophor C7002, Leucophor CS, and Leucophor C6902 (Sandoz Colors and Chemicals)

Properties	Clear brown liquids Anionic in character Good stabilities to acids, alkali salts, and hard water Not compatible with cationic compounds Compatible with anionic compounds, nonionic compounds, fillers and shading pigments, direct and acid dyes, acid and alkaline starches, wet strength resins
Application	Paper

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-560/2-75-002	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Preliminary Study of Selected Potential Environmental Contaminants - Optical Brighteners, Methyl Chloroform, Trichloroethylene, Tetrachloroethylene and Ion Exchange Resins		5. REPORT DATE July 1975
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16. ABSTRACT

A comprehensive review of the literature published from 1953 through 1973 was conducted to prepare this preliminary investigation report on the physical and chemical properties of optical brighteners, methyl chloroform, trichloroethylene, tetrachloroethylene and ion exchange resins, on environmental exposure factors related to their consumption and use, on the health and environmental effects resulting from exposure to these substances and on any applicable regulations and standards governing their use.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
optical brighteners cleaning solvents trichloroethylene methyl chloroform tetrachloroethylene ion exchange resins	-chemical properties -physical properties -environmental effects -environmental exposure	06/F,J,P,T 07/A,C,D

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