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A cross-sectional medical and industrial hygiene survey of workers exposed to carbon disulfide

by John Fajen, MS, Bruce Albright, MD, Sanford S Leffingwell, MD, MPH [1]

FAJEN J, ALBRIGHT B, LEFFINGWELL SS. A cross-sectional medical and industrial hygiene survey of workers exposed to carbon disulfide. *Scand j work environ health* 7 (1981): suppl 4, 20—27. In 1979, the National Institute for Occupational Safety and Health (NIOSH) conducted a cross-sectional medical and industrial hygiene survey of workers exposed to carbon disulfide in the manufacture of rayon staple. The purpose of the study was to define dose-response relationships at levels near the existing United States standard of 20 ppm. The plant chosen has been historically well controlled, with levels between 10 and 30 ppm for most of its history. Medical tests were designed to examine effects on the central and peripheral nervous systems, on the cardiovascular system (including the retinal vessels), on carbohydrate, trace mineral, and lipid metabolism, on testicular function, and on thyroid function. This paper describes the plant, the exposed and reference populations, and the tests used to determine the health effects of carbon disulfide. The data are still being analyzed, but preliminary evidence suggests that carbon disulfide exposure at levels below the present standard of 20 ppm is associated with adverse effects. On the basis of the analysis completed to date the safety of the standard of 1 ppm recommended by NIOSH does not appear to be established.

Key terms: occupational exposure, rayon, cardiovascular effects, neurological effects, psychological effects, endocrine effects, reproductive effects.

In May 1977 the National Institute for Occupational Safety and Health (NIOSH) released a criteria document with a recommended standard for occupational exposure to carbon disulfide. NIOSH recommended "that carbon disulfide concentration in workplace air not exceed 3 mg/cu m (1 ppm) as a 10 hour TWA (time weighted average) concentration during a 40-hour week [p 138]" (23). This recommendation represented a considerable change from the previous standard of 20 ppm.

The proposed standard was based on numerous human studies suggesting that carbon disulfide affects the cardiovascular system, the nervous system, the retinal vessels, and the reproductive system. Some of these studies were adequate but dealt with carbon disulfide exposures that were much higher than is usually seen in American workplaces. Other studies were incomplete in either design, exposure data, or statistical analysis.

As much of the available literature made the determination of a suitable standard difficult, a comprehensive medical study involving an American worker population exposed to the current standard of 20 ppm or less was planned and carried out in the spring of 1979.

Since its discovery by Lampadius in 1796 (8) carbon disulfide has found widespread use in many areas and in many cases has produced unwanted effects in humans that came in contact with it. Its use as an anesthetic gas caused hallucinations, headache, and nausea (29). Its use in the India-rubber industry, common in the mid 1850s, caused loss of "... will power ... [and caused] self-contempt" (6). With the onset of large-scale rubber production in the early 20th century, symptoms of mania

[1] National Institute for Occupational Safety and Health (NIOSH), Cincinnati, Ohio, United States.

Reprint requests to: Dr SS Leffingwell, Division of Surveillance, Hazard Evaluation and Field Studies, National Institute for Occupational Safety and Health, 4676 Columbia Parkway, Cincinnati, OH 45226, USA.

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were reported (25). As the viscose rayon industry developed, more varieties of carbon disulfide intoxication were reported. These included tingling and numbness of the extremities, weakness of limbs, loss of appetite, weight loss, severe and localized headache, sexual dysfunction, impaired vision, and gastrointestinal disturbances (9, 17). From these early descriptions of carbon disulfide intoxication, the concept of carbon disulfide toxicity as a multisystem disorder grew.

A review of the available literature shows a number of significant health effects that are now attributed to carbon disulfide. While space prohibits a detailed discussion of each, they have been enumerated in fig 1, with references to at least some of the more important papers detailing the investigational procedures and findings.

Study design

The cohort for this study was chosen from an American synthetic textile plant which has been in operation since 1948, when the rayon filament plant first went into operation. The rayon filament plant was joined by a viscose rayon staple plant in 1956, a nylon filament plant in 1963, a polyester filament plant in 1966, and a nylon-polyester staple plant in 1967. The rayon filament plant ceased production in 1974.

Individual work histories were obtained from the company before the study and were used in deciding eligibility for inclusion in the exposed and reference groups; the same information was used with the departmental exposure level data in the calculation of individual cumulative exposures. The exposed group was chosen from those members of the viscose rayon staple plant who had been employed in that plant for at least 1 a. Their employment prior to that time could have included the old rayon filament plants or one of the other synthetic fiber plants already listed.

The reference group was selected from either the polyester filament, nylon filament, or nylon-polyester staple plant. Those included had to have been employed at least 1 a in any or all of these plants. Workers from these areas with previous experience in either the rayon staple or filament plant were excluded from the reference group.

A number of job types, including general maintenance, yard work, etc, were excluded from both the exposed and reference groups because their work would take them into both carbon disulfide exposure and nonexposure areas. A few of these people were inadvertently included in the medical tests but were thereafter excluded from the statistical analysis.

Nonwhites were examined but were also excluded from both groups in the statistical analysis, since there were too few to analyze separately and race is a confounding factor in many of the cardiovascular studies that were used.

Of the 273 workers who were potentially available and who fit the study criteria for exposed workers, 189 (69.2 %) signed informed consent forms. For the reference population, 422 workers were originally asked to participate in the study; 244 (57.8 %) signed consent forms.

The historical carbon disulfide exposure levels varied from "very small" to 15—20 ppm, depending on the area being considered. Most rayon workers are assigned to specific jobs which they perform each workday. They can be identified according to their job location (eg, press operator, churn room, spinner). Some rayon

A. Cardiovascular effects
1. Hypertension (15, 34)
2. Coronary heart disease (15, 33, 34 — but see 36)
3. Impaired cardiac contractility (10)
4. Retinal microaneurysms (11, 12, 13, 16, 26, 30)

B. Psychiatric effects (5)

C. Neuropsychological effects
1. Peripheral neuropathies (18, 28, 35)
2. Psychomotor losses (14, 35)
3. Visual function alterations (27, 32)

D. Endocrine and metabolic effects
1. Diabetogenic (12 — but see 27, 31)
2. Hypercholesterolemia (34)
3. Thyroid disorders (2, 3)
4. Trace metal depletion (4, 7)

E. Reproductive effects (19, 20)

Fig 1. Health effects of carbon disulfide (references in parentheses).

staple workers, however, rotate to different jobs depending on the needs of the process (general relief operator). In order to determine the magnitude of carbon disulfide exposure, 8-h personal sampling pumps were placed on some workers in the major job categories (table 1). This was done on a number of different days at two different times (March and April 1979).

Current exposure for each major job type was determined from the mean of all the samples obtained for a specific job. For statistical purposes, each job was then placed into categories of definitely low exposure (less than 3 ppm), moderate exposure (3 ppm through 7.1 ppm), and definitely high exposure (greater than 7.1 ppm). A fourth category was necessary for a number of workers for whom no exposure data were available (eg, waste handlers, laboratory workers). This group was designated as "other."

In addition to carbon disulfide exposure, rayon staple workers had potential exposure to hydrogen sulfide, askarel, tin oxide, zinc oxide and sulfate, sodium hydroxide, and sulfuric acid. Hydrogen sulfide has been suggested as a possible confounding factor in previous studies on carbon disulfide, especially in viscose rayon plants. Its acute effects are well-known: cardiorespiratory failure (probably central) and possible convulsions. Subacute effects are related to the central nervous system (ie, headache, dizziness, staggering gait, tremor, weakness, and numbness of extremities). Chronic effects have not been fully substantiated but perhaps constitute a progression of subacute effects. Although the extent of interference of hydrogen sulfide in this study is uncertain, it is assumed to be small because exposure to hydrogen sulfide was found to be below the suggested standard. None of the other exposures are known to produce effects which could cause confounding results in this study.

Table 1. Average personal carbon disulfide exposure (ppm) by job assignment in the rayon staple plant.

Job description	Number of samples	Average	Standard deviation	Minimum	Maximum
Lye room operator	5	.59	0.40	0.04	0.99
Soaking press loader	2	1.1	0.34	0.90	1.38
Soaking press operator	2	1.1	0.35	1.01	1.51
Shredder operator	6	2.5	1.62	0.99	5.53
Churn operator	20	7.1	3.12	1.15	16.10
Dissolver operator	17	4.1	1.57	1.89	7.90
Receiving and filtration operator	2	3.7	0.24	3.5	3.84
Spinning top operator	2	3.4	0.05	3.33	3.41
Tank cleaner	2	8.0	10.00	0.95	15.1
General relief operator (chem)	22	4.4	2.57	0.04	11.2
Dye mix operator	7	5.1	1.98	3.37	9.0
Press packer and laundry room operator	6	4.7	1.42	3.31	6.9
General relief operator (finish)	44	4.5	3.44	0.40	13.9
Correction operator	3	1.3	0.56	0.62	1.60
Crystallizer and evaporator operator	4	7.1	6.31	1.41	13.8
Chemical mix operator	3	0.58	0.34	0.34	0.97
Salt unit operator	3	0.21	0.16	0.04	0.37
Saud filter and relief operator	5	1.7	0.70	0.95	2.83
Staple spinner	35	15.4	35.58	1.30	216.0
Tow patroller	3	11.8	5.48	6.09	17.0
Cutter operator	13	11.3	7.08	0.04	30.7
Dryer operator	1	1.1		1.09	1.1
Bale weighing operator	5	0.65	0.39	0.04	1.02
Washer operator	21	14.4	33.24	1.01	159.0
Unassigned	1	2.61		2.61	2.61

[a] Samples taken by the National Institute for Occupational Safety and Health in March and April 1979.

Plant description

The rayon staple plant consists of a continuously enclosed multilevel building which accepts raw materials for the process and converts these materials into a marketable bale of rayon staple. On the top floor at the beginning of the process, sheets of cellulose pulp are weighed and then placed in a soaking press containing caustic soda. When the cellulose has softened, the excess lye solution is squeezed out of the cellulose pulp by the press. The pulp is then placed in a shredding machine which produces crumbs of the cellulose. The crumbs are then aged in a temperature-controlled room. After ageing, the crumbs are dropped through the floor into a "churn," where they are mixed with liquid carbon disulfide. This mixture is then sent through a chute to the dissolving tank containing dilute caustic soda. Here, the crumbs are transformed into a viscose solution with the consistency of honey. The viscose solution is transported through pipes to a temperature controlled room for filtration and ageing under vacuum. After ageing, the viscose is again transported by pipes to the spinning room. The spinning room contains numerous troughs of dilute sulfuric acid, each of which has many tubes with attached thimble-like platinum cups called spinnerets protruding into the acid. Each spinneret is perforated with 10 to 10,000 small holes. Viscose from the ageing room is forced through the fine holes into the acid bath. This process coagulates the viscose to cellulose strands and releases some carbon disulfide vapor. The strands are gathered together to form a tow, which is passed to the cutter where "acid chips" of rayon staple are made. The chips pass over a conveyer belt for washing, and more carbon disulfide is removed from the product. Next, the staple is placed in a dryer where the previously wet product becomes fluffy and white. Staple is then passed to the bailer, and the finished bales are processed for shipment.

Industrial hygiene data

Past exposure

Air sampling data for carbon disulfide and hydrogen sulfide have been collected since the start-up of the plant in 1948. Personal sampling data for carbon disulfide have been collected since 1974. This information was microfilmed, coded, edited, and entered into the computer. The time study data were used in conjunction with the area sampling data to estimate personal exposure. Average exposure was determined for each job on a yearly basis (table 2). Cumulative exposure for a specific worker was determined by the multiplying of the number of years the worker held each job by the average exposure of that job in the years the worker held the job. The cumulative exposure of each job the worker held was summed to obtain the total exposure.

Current exposure

Air sampling was conducted to determine average personal exposures of workers to carbon disulfide and hydrogen sulfide in the exposed population.

Carbon disulfide sampling. Personal samples of carbon disulfide were taken from each job category in the rayon staple plant. The greatest numbers of samples were collected in the job categories with the highest potential for exposure (eg, cutter operator, staple spinner). The carbon disulfide samples were collected with commercially available 150-mg charcoal absorption tubes. They were desorbed with

Table 2. Average area sampling data (ppm) by area in the rayon staple plant from 1957 through 1978.[a]

Area	Number of samples	Average (ppm) 1957—1978
Churn room	297	8.02
Dissolving room	309	8.97
Spinning machines	226	7.34
At second stretch rollers	1,281	26.09
Along hot dip	960	17.2
At the cutter	1,256	19.2
Chip conveyer	393	33.5
Waste cutter	166	7.16
Correction operator desk	273	4.58
Basement receiving tank	157	4.99
Second bath tanks	158	6.22
Cooling tower	1	2.2
Spinning room	1	12.4

[a] Samples taken by the company.

benzene and analyzed by gas chromatography, utilizing a flame photometric detector with a sulfur filter (22).

The samples were collected at a flow rate of 20 ml/min for a full shift with MDA® and duPont low flow sampling pumps. The pumps were calibrated before and after the survey.

Hydrogen sulfide sampling. Personal samples of hydrogen sulfide were collected for most of the job categories in the spinning and cutting areas of the rayon plant. The greatest numbers of samples were collected for job categories with the highest potential for exposure. The hydrogen sulfide samples were collected in long-term direct reading detector tubes with the use of MDA and duPont low flow pumps, calibrated before and after the survey. The sampling time was approximately 4 h.

Reference population exposures

Personal air sampling was conducted to determine the average exposure of workers to caprolactam, ethylene glycol, dimethyl terephthalate, and methanol. These compounds were used exclusively in the reference environment. The reference population did not use carbon disulfide in their work processes. This procedure was carried out to develop a profile on the reference population and to determine if the levels found were significant enough to have confounding effects on the medical study.

Cross-sectional medical study

Subjects and methods

Prior to the study, the workers were seen in small groups, the purpose of the study and the nature of the tests were explained, and volunteers were solicited.

At the time of the study, the employer made space in the administrative area of the plant available to us, a NIOSH trailer was parked nearby and used for registration and check-out, and the cafeteria area was used during off-hours for blood drawing.

At the start of the actual screening, the employee reported to the trailer, where he was checked in and given a semen collection jar if he had volunteered for that portion of the study. He then went next door and upstairs to the testing area. Psychological tests were given first, then psychomotor tests, and then visual acuity and depth perception tests. The mydriatic drops were instilled and, during a planned delay to allow full dilation, the medical history questionnaire was administered by a trained interviewer. The employee was then examined by direct ophthalmoscopy and photographed with a Topcon retinal camera. He next moved to a room where a brief physical examination was performed, from there to the blood pressure, electrocardiographic, and systolic time interval tests, and finally to the nerve conduction area.

Blood drawing was done en masse at several dates during the three-week course of the study.

Cardiovascular effects

Hypertension. Blood pressure was determined after a 15-min rest period with the worker in a supine position. With the worker still supine, the pressure was measured twice from the right arm (unless an anatomic defect forced use of the left arm). A random-zero sphygmomanometer was used, to minimize observer error, and the same technician did all the measurements. The random-zero sphygmomanometer is a device which adds or substracts a random amount from the pressure reading. The amount of the change is not known until after completion of the measurement, so a technician will not unconsciously bias the results toward, for example, even numbers.

Coronary heart disease. A resting 12-lead electrocardiogram (ECG) was recorded for each subject. ECGs were read by three cardiologists and reported according to the Minnesota Code (2).

Impaired cardiac contractility. Systolic time interval was determined with instrumentation which simultaneously recorded ECG, apical phonocardiogram, and carotid pulse wave. It was measured from the onset of the QRS complex to the closing of the aortic valve, the time from onset of the QRS to opening of the aortic valve constituting the isovolumetric contraction time, and the time from aortic opening to aortic closure constituting the left ventricular ejection time (21, 37).

Retinal microaneurysms. Each subject underwent pupillary dilation with a short acting mydriatic. After dilation was complete, direct ophthalmoscopy was performed, and the results recorded. Each subject then had two pictures taken of each eye with a Topcon retinal camera, a monochromatic light source, and panchromatic film. The film was later processed and mounted as black and white slides. An ophthalmologist read the slides without knowledge of the subjects' identities and recorded the results. The results were reported separately for each subject's right and left eye as either normal, having definite or uncertain microaneurysms, or having definite or uncertain hemorrhages.

Psychiatric effects

Each participant was tested with the Profile of Mood States and with the mania scale drawn from the Minnesota Multiphasic Personality Inventory. Taken together, these scales measure each worker along six identifiable mood or affective states (tension-anxiety, depression-dejection, anger-hostility, vigor-activity, fatigue-inertia, confusion-bewilderment) and for mania.

Neuropsychological effects

Peripheral neuropathies. Ulnar and peroneal motor nerve conduction velocities and amplitudes were measured. If time permitted, sensory nerve conduction velocity and amplitude were determined for the sural nerve. Skin temperature was measured for each subject, and appropriate adjustments will be made in the calculations of velocity.

Psychomotor losses. Two tests were used to measure psychomotor function. In the Visual Choice-Reaction Time Test the subject had to move from a central button to one of eight buttons lighted in a random sequence. The time needed to move off the central button measured decision time, while the time from release of the central button to depression of the lighted button formed one measure of motor function. The Michigan Hand-Eye Coordination test required the subject to move a stylus through 119 holes in a plate. The test scores were the mean time needed to move the stylus from hole to hole and the variability in the interhole movement time.

Visual function alterations. Visual function was measured in two tests. The Neisser Test measured the rate of visual search by requiring the subject to look for target letters on a sheet containing rows of random arrangements of letters. Static visual acuity, depth perception, and peripheral vision were measured by standard methods.

Memory. The forward digit-span test required the subject to recite a series of up to eight digits in the same order shown on a video display screen.

Endocrine and metabolic effects

Diabetogenic. The fasting blood sugar was measured.

Hypercholesterolemia. Total cholesterol, triglycerides, and low and high density lipoproteins were measured with the subject in a fasting state.

Thyroid disorders. Thyroxin (T_4) and triiodothyronine (T_3) levels were determined from the fasting blood specimens.

Trace metal depletion. Zinc, copper, and total serum protein were determined from the blood samples.

Reproductive effects

Sperm count and morphology were determined on the subset of the cohort who were willing to volunteer. Volunteers were asked to abstain from sexual activity for at least 48 h before collection. Specimens were produced by masturbation, collected in a sterile container, and brought to the examination center where color and consistency were noted. The specimen was frozen and transported back to the University of Cincinnati for routine analysis.

Physical examination

A brief physical examination, looking mainly for conditions which might affect other tests, was provided.

Blood tests for possible confounding variables

Gamma glutamyl transpeptidase (GGTP) (with serum glutamate-oxalacetate transaminase and serum glutamate-pyruvate transaminase if GGTP abnormal) was measured to rule out any excess intake of alcohol, which might affect the outcome of the neuropsychological tests.

Hemoglobin was checked to rule out anemia as a cause of tachycardia, which might, in turn, affect systolic ejection time.

Data analysis

In order to develop dose-response curves, we will compare the outcomes of the tests with present and historical industrial hygiene data, as described before. The analysis of the data collected is still incomplete. An initial review of the data suggests that effects of low level exposure to carbon disulfide can be detected as increased frequencies of retinal microaneurysms and hemorrhages and as alterations in nerve conduction velocity. There may be differences in lipid patterns. The retinal changes appear to be present even in the group with the lowest exposure level, ie, less than 3 ppm. The final determination of these effects must, at a minimum, await analysis by cumulative exposure and by duration and latency of employment. Further study may be needed to define the relationships between effect and exposure with sufficient certainty for regulatory use.

References

1. Blackburn H, Keys A, Simonson E, Rautaharju P, Pansar S. The electrocardiogram in population studies — A classification system. Circulation 21 (1960) 1160—1175.
2. Cavalleri A. Serum thyroxin in the early diagnosis of carbon disulfide poisoning. Arch environ health 30 (1975) 85—87.
3. Cavalleri A, Taccola A, Graovac-Leposavic LJ, Maugeri U, Djuric D. The serum thyroxin and the achilles-tendon reflex in workers exposed to carbon disulfide. Med lav 62 (1971) 412—415.
4. Cohen AE, Scheel LD, Kropp JF, Stockell FR, Keenan RG, Mountain JT, Paulus HJ. Biochemical mechanisms in chronic carbon disulfide poisoning. Ind hyg j (1959) 305—323.
5. Davidson M, Feinleib M. Carbon disulfide poisoning: A review. Am heart j 82 (1972): 1, 100—114.
6. Department of Labor and Industry, Occupational Disease Prevention Division. Survey of carbon disulfide and hydrogen sulphide hazards in the viscose rayon industry. Harrisburg, PA 1938. 69 p. (Bulletin no 46).
7. El-Gazzer R, El-Sadik YM, Hussein M. Changes in zinc and serum proteins due to carbon disulfide exposure. Br j ind med 30 (1973) 284—288.
8. Folkins HO. Carbon disulfide. In: Interscience Publishers. Kirk-Othmer encyclopedia of chemical technology. Volume 4. New York, NY 1964, pp 370—385.
9. Francine AP. Acute carbon disulfide poisoning. Am med 9 (1905) 871.
10. Franco G, Malamani T. Systolic time intervals as a measure of left ventricular function in viscose rayon workers exposed to carbon disulfide. Scand j work environ health 2 (1976) 107—114.
11. Goto S, Hotta R. The medical and hygienic prevention of carbon disulfide poisoning in Japan. In: Brieber H, Teisinger J, ed. Toxicology of carbon disulfide. Exerpta Medica Foundation, Amsterdam 1967, pp 219—230.
12. Goto S, Hotta R, Sugimoto K. Studies on chronic carbon disulfide poisoning — Pathogenesis of retinal microaneurysm due to carbon disulfide, with special reference to a subclinical defect of carbohydrate metabolism. Int Arch Arbeitsmed 28 (1971) 115—126.
13. Goto S, Sugimoto K, Hotta R, Fujioka Y, Graovac-Leposavic L, Savic SM, Jovicic M. Retinal microaneurysm in carbon disulfide workers in Yugoslavia. Prac lek 24 (1972) 66—70.
14. Hänninen H. Psychological picture of manifest and latent carbon disulfide poisoning. Br j ind med 28 (1971) 374—381.
15. Hernberg S, Partanen T, Nordman CH, Sumari P. Coronary heart disease among workers exposed to carbon disulfide. Br j ind med 27 (1970) 313—325.
16. Hotta R, Sugimoto K, Goto S. Retinopathia sulfocarbonica and its natural history. Acta soc ophthalmol jpn 76 (1972) 1561—1566.
17. Jump HD, Cruice JM. Chronic poisoning from bisulfide of carbon. Univ penn med bull 17 (1904) 193—196.
18. Knave B, Kolmodin-Hedman B, Persson HE, Goldberg JM. Chronic exposure to carbon disulfide: Effects on occupationally exposed workers with special reference to the

nervous system. Work environ health 11 (1974) 49—58.
19. Lancranjan I. Alterations of spermatic liquid in patients chronically poisoned by carbon disulfide. Med lav 63 (1972) 29—33.
20. Lancranjan I, Popescu HI, Kelpsch I. Changes of the gonadic function in chronic carbon disulfide poisoning. Med lav 60 (1969) 566—571.
21. Lewis RP, Leighton RF, Forester WF, Weissler AM. Systolic time intervals. In: Weissler AM, ed. Noninvasive cardiology. Grune and Stratton Publishers, New York & London 1973, pp 301—368.
22. National Institute for Occupational Safety and Health. Manual of analytical methods. Second ed, vol 3. Department of Health Education and Welfare, 1977. (Method no S248).
23. National Institute for Occupational Safety and Health. Criteria for a recommended standard: Occupational exposure to carbon disulfide. Department of Health, Education and Welfare 1977.
24. Oleniacz W, Plamieniak Z. Lipid metabolism disturbances in chronic carbon disulfide poisoning. Pol arch med wewn 33 (1963) 1179—1182.
25. Oliver, ed. India rubber-Dangers incidental to the use of bisulphide of carbon and naphtha. In: CP Dutton & Co. Dangerous trades. New York, NY 1902, pp 470—474.
26. Raitta C, Tolonen M, Nurminen M. Microcirculation of ocular fundus in viscose rayon workers exposed to carbon disulfide. Albrecht von Graefes Arch Klin Exp Ophthalmol 191 (1974) 151—164.
27. Savic S. Influence of carbon disulfide on the eye. Arch environ health 14 (1961) 325—326.
28. Seppäläinen AM. Neuro physiologic findings in carbon disulfide exposure. In: Xintaras C, Johnson BL, deGroot I, ed. Behavioral toxicology. National Institute for Occupational Safety and Health, Cincinnati, OH 1974, pp 64—72.
29. Simpson JY. Notes on the anesthetic effects of chloride of hydrocarbon, nitrate of ethyle, benzin, aldehyde, and bisulpheret of carbon. Mon j med sci 8 (1848) 740—745.
30. Sugimoto K, Goto S, Hotta R. Studies on chronic carbon disulfide poisoning: A 5-year follow-up study on retinopathy due to carbon disulfide. Int arch occup environ health 37 (1976) 233—248.
31. Sugimoto K, Goto S, Taniguchi H, Baba T, Raitta C, Tolonen M. Ocular fundus photography of workers exposed to carbon disulfide: A comparative epidemiological study between Japan and Finland. Int arch occup environ health 39 (1977) 97—101.
32. Szymankowa G. Obserwacje dzalaniem CS_2 na narzad wzroku u prakownikaz wytworni wlokien syntetycznych. Klin oczna 38 (1968) 41—44.
33. Tolonen M, Hernberg S, Nordman C, Goto S, Sugimoto K, Baba T. Angina pectoris, electrocardiographic findings and blood pressure in Finnish and Japanese workers exposed to carbon disulfide. Int arch occup environ health 37 (1976) 249—264.
34. Tolonen M, Hernberg S, Nurminen M, Tiitola K. A follow-up study of coronary heart disease in viscose rayon workers exposed to carbon disulfide. Br j ind med 32 (1975) 1—10.
35. Tuttle TC, Wood GD, Giether CB. Behavioral and neurological evaluation of workers exposed to carbon disulfide. National Technical Information Service, Springfield, VA 1976. (NTIS PB Rep 1976, PB-274764).
36. Vertin PG. Incidence of cardiovascular diseases in the Dutch viscose rayon industry. J occup med 20 (1978) 346—350.
37. Weissler AM. Current concepts in cardiology: Systolic-time intervals. NEJM 296 (1977) 321—324.