Cross-sectional Study of Respiratory Symptoms and Pulmonary Functions in Rayon Textile Workers with Special Reference to H₂S Exposure

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Abstract: A cross-sectional study on pulmonary functions and respiratory symptoms was undertaken in Japanese male workers in 18 viscose rayon plants to detect pulmonary effects associated with viscose exposure, especially to H₂S. Measurement of the occupational exposure level (OEL) of H₂S by personal passive diffusion dosimetry, and the forced expiratory flow-volume test before and after an eight-hour shift on the same workday was undertaken in 30 matched pairs of exposed and non-exposed workers. The OEL of H₂S was 0.3 to 7.8 ppm, 3 ppm on the average, for the viscose exposed workers and less than 0.1 ppm for the referents. No significant difference in the eight-hour pulmonary function changes between the pairs was observed, and no significant correlation between the individual pulmonary function changes and individual OEL of H₂S was obtained. Indices of the forced expiratory flow-volume test for 324 workers appeared to be better in exposed non-smokers than in non-exposed non-smokers. The prevalence rates of respiratory symptoms in 2379 exposed and 2968 referent workers using a modified self-administered BMRC questionnaire showed significant associations with smoking habits, but not with rayon work-history. No evidence of any appreciable effect of viscose exposure on pulmonary functions and symptoms was revealed in the Japanese rayon plant workers.

Key words: Hydrogen sulfide—Flow-volume curve—Prevalence of respiratory symptoms—Viscose rayon—Matched pair—Occupational exposure level

INTRODUCTION

The principal health hazards in viscose rayon fiber plants have been chronic carbon disulfide (CS₂) intoxication (Kubota; Hernberg *et al.*; Hanninen; Fajen

et al.)¹⁻⁴⁾ and the acute irritative effects of hydrogen sulfide (H_2S) on the conjunctiva (Nyman; Milby),^{5,6)} while pulmonary effects due to these chemicals have been a minor occupational health problem. Acute pulmonary effects of H_2S exposure at high concentrations, i.e., more than 500 ppm, were reported to be death by paralysis of the respiratory center (Simson *et al.*; Smith *et al.*)^{7,8)} or hemorrhagic pulmonary edema in near-fatal cases (Kamper; Burnett *et al.*)^{9,10)} These conditions resulted from accidental exposure to high concentrations of H_2S . However, there have been few reports on the acute subclinical pulmonary effects of H_2S exposure at low concentration levels, and the long-term effects of H_2S have not been well documented. The Occupational Safety and Health Administration of the United States has recommended routine periodical pulmonary examinations for H_2S exposed workers (NIOSH/OSHA).¹¹⁾ In Japan, the general public living near viscose rayon plants has frequently expressed concern about possible health hazards associated only with the odor or corrosive nature of H_2S .

We planned a short-term one workday study and a cross-sectional prevalence study to ascertain whether exposure to viscose vapors, especially H_2S , would have any acute single workday or long-term effect on pulmonary functions and respiratory symptoms in viscose rayon workers who had been exposed steadily for some years in the same work environment. The one-workday study was designed to detect the one-day immediate effects of H_2S exposure on pulmonary functions with reference to the personal index of exposure. In the cross-sectional study, the pulmonary function indices of the forced expiratory flow-volume test and the prevalence rates of respiratory symptoms assessed by a standardized questionnaire were used to determine the effects of long-term exposure as compared to non-exposed workers in the same plants. The objective of the study was to assess reasonable estimations of the effects of occupational exposure by combining the two sets of studies.

SUBJECTS AND METHODS

One-workday study on diurnal occupational exposure

In October 1980, 30 male H_2S -exposed workers who engaged in spinning, cutting or refinery work were selected from three viscose rayon fiber plants. From each of the three plants, the same number of non-exposed workers matched to each of the exposed workers as to smoking habits, age and height was selected. Maximum deviations of the matched factors within the pairs were five cigarettes per day, three years in age and 4 cm in height. None of the subjects had a history of severe respiratory disorders due to any cause or acute respiratory distress resulting from acute H_2S poisoning.

The occupational exposure level (OEL) of H_2S exposure was measured by a passive diffusion dosimeter developed by the authors (Nakaza *et al.*)¹²⁾ The dosimeter is a small badge-type polyethylene tube containing a sheet of filter paper

impregnated with lead acetate solution. Each exposed and reference worker wore a sampler on his lapel for 6.5 actual work-hours during the eight-hour shift. The environmental concentrations of H₂S and CS₂ in the working areas were measured at representative points in the workplace by the methylene blue method (APHA)¹³⁾ and the diethylamine copper method (McKee),¹⁴⁾ respectively. During the survey in three plants, the geometric mean concentration of H₂S in the room air was 1.06 ppm (geometric standard deviation, 1.82), and that of CS₂ was 2.90 ppm (g.s.d., 2.62). The mean concentrations for all 18 plants are discussed elsewhere in this text.

The forced expiratory flow-volume curves were recorded as the indices of pulmonary ventilatory capacities and of airway obstruction using an electronic spirometric instrument (Autospiroanalyzer ASC-1000, Asahi Medical). The flow-volume curves with three acceptable forced expiratory maneuvers before and after work were obtained in each subject by a chest physician, who was blinded to information as to the worker's H₂S exposure. The curve with the maximal sum of FVC and FEV_{1.0} (Sorensen *et al.*)¹⁵⁾ was used for analysis, and the following indices were printed out: forced vital capacity (FVC), forced expiratory volume in one second (FEV_{1.0}), peak expiratory flow rate (PEFR), maximum expiratory flow rate at 75% (MEF₇₅), at 50% (MEF₅₀) and at 25% (MEF₂₅) of the FVC, percentage rate of FEV_{1.0} to FVC (FEV_{1.0}%), and ratio of MEF₅₀ to MEF₂₅ (MEF₅₀/MEF₂₅). The flow-volume tests were performed twice on the same day. The initial measurements were done in the morning (6 to 7 a.m.) a few minutes prior to starting a routine day shift and the second at the end of the day (2 to 3 p.m.). Smokers were asked to refrain from smoking for at least one hour before the measurements. The measurement of H₂S exposure (OEL) and the pulmonary function tests were conducted on the same workers on the same day.

Cross-sectional prevalence study on exposure-referent respiratory symptoms

In the three representative viscose rayon plants of a total of 18 throughout Japan, the flow-volume test was performed utilizing the same procedure as described above on 324 subjects, 115 exposed workers and 209 referents, in which the 30 pairs of exposed and non-exposed workers appearing in the former study were included. Each subject underwent the pulmonary function measurement once a day between 10 a.m. and 2 p.m., and, for the 30 pairs, the data of the second measurement (end of work) were used for analysis. Prediction equations from the data of non-exposed healthy workers in other industries in Japan (Sakurai *et al.*)¹⁶⁾ were used to estimate the expected pulmonary function values.

The prevalence rates of respiratory symptoms were obtained by utilizing a self-administered standard questionnaire in male workers in 18 viscose rayon fiber plants with the assistance of the Japan Chemical Fiber and Textile Association. The questionnaire, which was a slightly revised Japanese version of the British

Medical Research Council's short questionnaire on respiratory symptoms with enforced occupational history, was distributed to 7200 workers through plant physicians or plant health supervisors of the individual plants and returned directly to the authors. The number of replies was 6670, for a response rate of 93%. Subjects with experience of work in a dusty job or apparent pulmonary diseases before employment as well as incomplete answers to the questionnaires were omitted from the analysis. Thus, 5347 questionnaires from 2379 exposed workers and 2968 referents were usable for analysis. Logistic regression analysis (Cox; Lemeshow *et al.*)^{17,18)} was used for the evaluation of the associations between the respiratory symptoms and several related variables. To compare the results of the self-administered questionnaire with the interview method, 62 workers in the three plants were directly interviewed by the investigators using the same questionnaire about one month after the self-administered inquiry.

RESULTS

One-workday study

Table 1 shows the area distribution of the plants surveyed and the age, height, weight and cigarette consumption of the H₂S exposed workers and the matched referents. Because matching for cigarette smoking habits was undertaken on the basis of current smoking patterns, three former smokers who had quit more than three years before were categorized as non-smokers in the reference group. Between the 30 exposed workers and their matched referents, no significant difference in the prevalence rates of individual respiratory symptoms was noted. As shown in Table 2, no significant difference within the matched pairs was seen

Table 1. Area distribution, physical characteristics, smoking habits and duration of exposure of 30 matched pair in three plants

	H ₂ S-exposed workers (n=30)	Reference workers (n=30)
Area distribution		
North	7	7
Inland-sea	11	11
South	12	12
Age (year), mean $\pm$ s.d.	39.0 $\pm$ 9.5	40.0 $\pm$ 8.3
Height (cm), mean $\pm$ s.d.	166.3 $\pm$ 6.5	165.6 $\pm$ 3.8
Weight (kg), mean $\pm$ s.d.	63.2 $\pm$ 7.8	62.3 $\pm$ 6.5
Current smoking habits	24 (80%)	24 (80%)
$\leq$ 14 cigarettes/day	9	8
15-24 cigarettes/day	14	12
$\geq$ 25 cigarettes/day	1	4
Number of nonsmokers	6	3
Number of exsmokers	—	3
Duration of exposure (year), mean $\pm$ s.d.	12.3 $\pm$ 7.7	—

Table 2. Pulmonary functions^a in matched H₂S-exposed and referent pairs (mean $\pm$ s.d.) and significance of difference

	H ₂ S-exposed workers (n=30)	Reference workers (n=30)	Paired t-test
FVC (l)	4.25 $\pm$ 0.73	4.25 $\pm$ 0.64	n. s.
FEV _{1.0} (l)	3.55 $\pm$ 0.59	3.53 $\pm$ 0.60	n. s.
FEV _{1.0} %	83.8 $\pm$ 4.89	83.0 $\pm$ 5.53	n. s.
PEFR (l/sec.)	8.67 $\pm$ 1.90	8.48 $\pm$ 1.34	n. s.
MEF ₇₅ (l/sec.)	8.20 $\pm$ 1.82	8.04 $\pm$ 1.29	n. s.
MEF ₅₀ (l/sec.)	4.89 $\pm$ 1.24	4.81 $\pm$ 1.29	n. s.
MEF ₂₅ (l/sec.)	1.74 $\pm$ 0.55	1.71 $\pm$ 0.67	n. s.
MEF ₅₀ /MEF ₂₅	3.20 $\pm$ 0.95	3.07 $\pm$ 0.84	n. s.

^a: Measured in the morning before beginning the day shift.

n.s.: No significant difference between the pair.

Fig. 1. Frequency distribution of personal exposure to H₂S during work hours.

in the initial pulmonary function values by the paired *t*-test, and it might be conceivable that no long-term effects of viscose exposure on pulmonary functions was indicated. Figure 1 shows the frequency distribution of occupational exposure level for H₂S, as expressed by ppm, during 6.5 actual exposure hours in eight-hour shift work. The range of exposure levels (OEL) was 0.3 ppm (0.4 mg/m³) to 7.8 ppm (11.0 mg/m³), 3 ppm on the average, for the viscose-exposed workers and less than 0.1 ppm for the referents. Table 3 lists the percentage change rates of the pulmonary functions, i.e., the ratio of the second values to the initial values on the same day. No significant difference was seen by the paired *t*-test between diurnal changes in the exposed workers and those in the referents.

Table 4 shows the relationship in multiple regression between the percentage

Table 3. Percentage change rates of pulmonary functions before and after an eight-hour day shift (mean $\pm$ s.d.)

	H ₂ S-exposed workers (n=30)	Non-exposed workers (n=30)	Paired t-test
FVC	0.2 $\pm$ 6.8	-1.0 $\pm$ 4.1	n. s.
FEV _{1.0}	2.8 $\pm$ 5.8	0.0 $\pm$ 3.4	n. s.
FEV _{1.0} %	3.0 $\pm$ 4.3	2.3 $\pm$ 3.5	n. s.
PEER	4.7 $\pm$ 15.4	1.1 $\pm$ 13.0	n. s.
MEF ₇₅	5.5 $\pm$ 14.7	4.0 $\pm$ 15.1	n. s.
MEF ₅₀	8.0 $\pm$ 14.3	4.4 $\pm$ 15.3	n. s.
MEF ₂₅	19.7 $\pm$ 35.4	10.9 $\pm$ 27.2	n. s.
MEF ₅₀ /MEF ₂₅	-3.4 $\pm$ 19.1	-1.2 $\pm$ 19.6	n. s.

n.s.: No significant difference between the pair.

Table 4. Regression coefficients, percentage change of pulmonary functions in the same day versus explanatory variables

Percentage change of pulmonary function	Variables ^a				n	R ²
	Age	Ht & Wt	Smoking habits	H ₂ S exposure		
FVC	.316	-.027	-.070	-.081	30	.206
FEV _{1.0}	.275	-.018	-.110	-.053	30	.245
FEV _{1.0} %	-.026	.009	.047	0.30	30	.067
PEFR	-.007	.005	-.286	.066	30	.048
MEF ₇₅	-.011	.014	-.258	.036	30	.050
MEF ₅₀	.080	.033	-.213	.200	30	.037
MEF ₂₅	-.072	.023	-.205	.071	30	.042
MEF ₅₀ /MEF ₂₅	.020	-.012	.148	.230	30	.035

^a: Age—year; Ht & Wt—Broca's index; Smoking habits—daily consumption (cigarettes/day); H₂S-exposure—occupational exposure level (ppm).

change of pulmonary functions and such variables as age, anthropometric characteristics, smoking habits and personal exposure concentration of H₂S (OEL) for the 30 exposed workers. The partial regression coefficients were not statistically significant in respective variables. The results indicated that diurnal occupational exposure to H₂S did not affect the pulmonary functions in the exposed workers.

Cross-sectional prevalence of respiratory symptoms

The long-term effects of viscose exposure on pulmonary functions were analyzed in 324 workers divided into four groups categorized by viscose work experience and smoking habits, as indicated in Table 5. In the same Table, the percentage ratios of the observed pulmonary functions to the predicted values computed by the prediction equations are shown. Daily cigarette consumption and duration of smoking in Groups 1 (exposed) and 3 (non-exposed) were 16.5 $\pm$ 5.4 cigarettes and 18.2 $\pm$ 4.8 years and 19.1 $\pm$ 6.1 cigarettes and 17.6 $\pm$ 5.1 years, respectively.

Table 5. Age and percentage-predicted pulmonary functions by viscoie exposure and smoking categories (mean $\pm$ s.d.)

	Viscose exposed workers		Non-exposed workers	
	Smoker Group 1 (n=85)	Non-smoker Group 2 (n=30)	Smoker Group 3 (n=125)	Non-smoker Group 4 (n=84)
Age (year)	40.5 $\pm$ 10.1	41.0 $\pm$ 9.1	38.6 $\pm$ 9.8	39.5 $\pm$ 8.8
Cigarette smoking				
Duration (year)	15.4 $\pm$ 5.2	—	17.2 $\pm$ 5.8	—
Cigarettes per day	17.1 $\pm$ 4.7	—	15.8 $\pm$ 5.1	—
FVC	105.0 $\pm$ 11.1	108.3 $\pm$ 10.2 ^c	103.0 $\pm$ 12.9	102.6 $\pm$ 13.0
FEV _{1.0} %	97.8 $\pm$ 6.9	100.2 $\pm$ 6.7	99.5 $\pm$ 5.5	99.0 $\pm$ 5.8
FEV _{1.0}	102.7 $\pm$ 13.0	107.4 $\pm$ 11.3	102.3 $\pm$ 13.3	102.4 $\pm$ 13.2
PEF	96.8 $\pm$ 17.7	105.9 $\pm$ 15.8 ^{a,b,c}	93.3 $\pm$ 19.2	94.8 $\pm$ 19.9
MEF ₇₅	100.0 $\pm$ 19.9	109.3 $\pm$ 20.7 ^{a,b,c}	95.7 $\pm$ 20.9	99.2 $\pm$ 26.2
MEF ₅₀	96.0 $\pm$ 27.6	104.9 $\pm$ 32.9 ^c	102.0 $\pm$ 27.6 ^d	95.2 $\pm$ 24.8
MEF ₂₅	92.9 $\pm$ 39.1	105.4 $\pm$ 39.8	99.5 $\pm$ 35.5	99.0 $\pm$ 35.8
MEF ₅₀ /MEF ₂₅	107.0 $\pm$ 26.1	102.1 $\pm$ 28.1	104.1 $\pm$ 24.1 ^d	96.8 $\pm$ 20.6

a: $p < 0.05$, Group 2 vs Group 1.b: $p < 0.01$, Group 2 vs Group 3.c: $p < 0.05$, Group 2 vs Group 4.d: $p < 0.05$, Group 3 vs Group 4.

Duration of involving H₂S exposure was 11.7 $\pm$ 5.9 years in Group 1 and 12.6 $\pm$ 6.8 years in Group 2. Of the 115 H₂S exposed workers, three were said to have so called "gaseous eyes" or chemical keratoconjunctivitis due to H₂S 10 years earlier. The PEFR and MEF₇₅ were significantly higher in the non-smoking H₂S-exposed group than in the other three groups. When the non-smoking H₂S exposed group and the non-smoking non-exposed group were compared, the FVC and MEF₅₀ were significantly higher in the former group. Thus, no adverse effects of long-term viscose exposure on pulmonary function were noted in these results.

In the cross-sectional prevalence study on respiratory symptoms for detecting the long-term effects of viscose exposure, 62 workers in three plants were interviewed by one of the authors using the same standard questionnaire one month after the survey by the self-administered method. Table 6 shows the comparison of the two methods with regard the responses to some principal symptom items. Although self-administered response rates generally tended to be higher than those obtained by interviews, no significant difference was found in this case by the chi square goodness of fit test.

Using the logistic regression model as stated in the chapter of subjects and methods,^{17,18)} multifactorial associations of the respiratory symptoms and the environmental and social variables were obtained (Table 7). The means and standard deviations of the variables were 39.6 $\pm$ 9.9 for age, 1.46 $\pm$ 0.79 for location of plants, 1.08 $\pm$ 0.55 for history of education, 0.83 $\pm$ 0.43 for marital status, 0.54 $\pm$ 0.44 for work category, 0.08 $\pm$ 0.27 for type of shift, 0.65 $\pm$ 0.83 for duration of viscose exposure and 1.41 $\pm$ 0.83 for smoking habits. The regres-

Table 6. Response in self-administered and interview methods (n=62)

No. ^α	Symptoms	Number (%) of questionnaire responses		
		Self-administered positive	Interview positive	positive Both
1	Cough in morning	12 (19.4)	10 (16.1)	9
6	Phlegm in morning	15 (24.2)	14 (22.6)	12
12a	Cough and phlegm	4 (6.5)	0 (0)	0
14a	Breathlessness	10 (16.1)	9 (14.5)	9
15a	Wheezing	13 (21.0)	11 (17.7)	10
	Experience of lung related diseases	4 (6.5)	3 (4.8)	3

α: Question code number of BMRC questionnaire (1976).

Table 7. Logistic regression analysis^α of prevalence of pulmonary symptoms and independent variables (n=5347, 18 plants)

No. ^β	Symptoms	Variables ^γ							
		Age	Location	Education	Marital status	Work category	Shift	Viscose exposure	Smoking habits
1	Cough in morning	.142*	.291	.001	.355	-.074	-.143	-.008	.549**
6	Phlegm in morning	.015	.297	.149*	.033	-.312	-.119	.186	.503**
12a	Cough & phlegm	.022	.216	.295*	.386	-.418	-.185	-.127	.102
14a	Breathlessness	.146**	.045	-.062	.288	.049	-.191	.016	.169**
15a	Wheezing	-.134	-.110	.188*	.045	-.338	-.239	-0.40	.173**
	Experience of lung related diseases	.306	-.078	.188	-.148	-.055	-.114	-.176	.063

*: Statistically significant coefficient at 0.05 level.

**: Statistically significant coefficient at 0.01 level.

α: Log odds (λ_i) = $A_0 + A_1 \cdot \text{Age} + A_2 \cdot \text{Location} + A_3 \cdot \text{Education} + A_4 \cdot \text{Marital status} + A_5 \cdot \text{Work category} + A_6 \cdot \text{Shift} + A_7 \cdot \text{Viscose exposure} + A_8 \cdot \text{Smoking habits}$.

β: Question code number of BMRC questionnaire (1976).

γ: Age (years); Location (Southern=1 Inland sea=2, Central=3, Northern=4); Education (Junior high school=1, Senior high school=2, College or higher=3); Marital status (Not married=0, Married=1); Work category (Office worker=0, Others=1); Shift (Daytime worker=0, Shift worker=1); Viscose exposure (No history of viscose work=0, 1-9 years=1, 10-19 years=2, More than 20 years=3); Smoking (Never smoked=0, Former smoker=1, Current smoker=2).

sion coefficients for all the variables are also listed in the same Table. Major significant associations existed for factors related to smoking habits and history of education, but there were no significant associations between the presence of symptoms and the duration of viscose exposure.

Table 8 shows the prevalence rates of respiratory symptoms by smoking category for the 40-to-49 age group. The results clearly indicated that the rate increased as the amount of smoking rose. The same relationship was found in the other age groups as well. The difference of the prevalence rates between workers who had been exposed for more than 10 years and the non-exposed referents was also

Table 8. Prevalence rates of pulmonary symptoms by smoking category, 40-49 years

No. ^α	Symptoms	Non-smokers (n=509)	Light smokers ^β (n=635)	Medium & heavy ^γ smokers (n=1029)
1	Congh in morning	4.6	7.3 ^c	11.8 ^{aa, b}
6	Phlegm in morning	8.4	12.7 ^c	18.5 ^{aa, bb}
12a	Cough & Phlegm	1.6	2.8	3.6 ^a
14a	Breathlessness	11.3	15.0	15.8 ^a
15a	Wheezing	9.9	13.6	17.2 ^{aa}
	Experience of lung related diseases	3.4	3.6	3.7

α: Question code number of BMRC questionnaire (1976).

β: Former smokers (n=23), and smokers who consume less than 15 oigarettes per day.

γ: Smokers who consume 15 or more cigarettes per day.

a: p<0.05

aa: p<0.01 } Non-smoker vs medium & heavy.

b: p<0.05

bb: p<0.01 } Light smoker vs medium & heavy.

found to be insignificant in each smoking category.

The results obtained from the two sets of studies, diurnal exposure and cross-sectional prevalence of respiratory symptoms, may well lead to the conclusion that viscose exposure, especially to H₂S, would not cause adverse pulmonary effects in the course of routine long-term occupational exposure under current work conditions.

DISCUSSION AND CONCLUSION

Repeated short-term or instant peak exposure to a toxic substance with reversible physiological effects may lead to a subsequent chronic irreversible impairment, if each stimulus is effective enough to induce a biological change. The outcome may be recognized by a cross-sectional prevalence study in an occupational, exposure-referent population. Based on this hypothesis, two types of epidemiological designs were adopted simultaneously in the present study, a one-day effect of exposure study in a selected small number of rayon plant workers and cross-sectional prevalence rates of respiratory symptoms in a large number of rayon workers throughout the industry. It has been reported (Holland *et al.*; Leader *et al.*)^{19,20} that, in London, recurrent episodes of respiratory tract distress at young ages have led to subsequent chronic ventilatory impairment or illness.

In the diurnal exposure study, matched pair sampling and the regression procedure was adopted to remove confounding bias. Those methods have been recommended in observational epidemiological studies (Rubin).²¹ The results indicated there is no exposure-response gradient between the personal occupational exposure level (OEL) and the individual degree of diurnal effects on pulmonary

function. These negative results might be due to insufficient environmental stimulation or weak sensitivity of physiological parameters capable of detecting the effects, despite pertinent matching procedures for age, sex, height and cigarette smoking habits, and careful performance of measurements of pulmonary function designed for before and after occupational exposure, as well as painstaking application of the H₂S personal dosimeter to the pairs. The ventilatory capacity obtained from forced expiratory flow-volume curves has been determined to be a sensitive indicator for detecting the effects of environmental pollution in epidemiological studies (Stanescu).²²⁾ To avoid technical error, every pulmonary measurement was undertaken by a single trained lung physician with his single epidemiologically approved instrument.

When any significant difference in the function was detected between the pair, it might reasonably be considered that the result was induced by viscose vapor, that is, at least three common chemical components existing in the environment, H₂S, CS₂ and H₂SO₄. The annual average concentration of co-existing gaseous confounders in the spinning rooms of 18 plants was reported from the internal information of the Japan Chemical Fiber and Textile Association as follows; 1.3 ppm for H₂S, 4.0 ppm for CS₂ and less than 0.1 mg/m³ for H₂SO₄. The respective occupational threshold limit values are 10 ppm for H₂S and CS₂ and 1 mg/m³ for H₂SO₄ (JAIH).²³⁾ Adaptation to H₂S, especially to its odor, should be taken into consideration, although Poda²⁴⁾ stated that no sensitivity change has been observed after over-exposure to H₂S. The association between odor of H₂S and pulmonary function, though not involved in this study, is a matter to be further investigated.

It must be noted that, in percentage-predicted pulmonary functions of viscose exposed workers by smoking category (Table 5), non-smoking viscose workers appeared to have higher values in FVC, PEFR and MEF₇₅ than non-smoking referents, and PEFR and MEF₇₅ were also higher than in other groups. These peculiar findings, that is the favorable values in non-smoking viscose-exposed workers, may be interpreted as not only indicating no adverse effects of viscose exposure, but may also be a result of "health promotion effects" that may be due to more intensive occupational health care for the exposed workers than the non-exposed or there may be "healthy worker selection effects" (Vinni *et al.*),²⁵⁾ that is relatively healthy workers were selected to do at the preplacement.

In the comparison of the two questionnaire methods, self-administered and interview, slightly higher prevalence rates of respiratory symptoms were obtained in the former. It has been reported that self-completion surveys usually yields significantly greater numbers of positive responses (Mittman *et al.*).²⁶⁾ The difference of the prevalence rates in the present study was so small (Table 6) that both methods could be considered acceptable.

It has been well documented that prevalence rates of respiratory symptoms are always higher in smokers than in non-smokers (Brinkman *et al.*; Hrubec *et*

al.).^{27,28)} In our results, significant associations were found between positive respiratory response and such variates as smoking habits and education, but not duration of H₂S exposure (Table 7). This might confirm that there were no long-term chronic effects of H₂S exposure on respiratory symptoms and the prevalence of respiratory symptoms increased as cigarette consumption increased (Tables 7 and 8). The significance of the positive relationship between the educational levels and the prevalence of respiratory symptoms might be associated with "urban-rural factors" (Holland *et al.*).²⁹⁾

Supplemented with the one-day exposure study on 30 matched pair workers, the negative results of the cross-sectional prevalence study on respiratory symptoms in 5347 viscose rayon workers in this country may lead to the conclusion that H₂S exposure, at least 3 ppm of occupational exposure level (OEL) or 1.3 ppm of annual mean concentration in the working room, causes neither acute nor chronic appreciable adverse effects on pulmonary function and respiratory symptoms.

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