

# Respiratory Function of Textile Workers Employed in Dyeing Cotton and Wool Fibers

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*A group of 135 textile dyeing workers (97 male and 38 female) was studied for the prevalence of acute and chronic respiratory symptoms and lung function changes. Respiratory symptoms were elicited by a standardized questionnaire, and lung function testing was performed before and after the morning shift by recording maximum expiratory flow-volume (MEFV) curves. In addition, 103 nonexposed control workers were studied. The prevalence of all chronic respiratory symptoms was significantly higher in the exposed than in the control workers; in particular, the prevalence of occupational asthma was 6%. The exposed nonsmoking workers had more complaints than the controls who were nonsmokers. As expected, most of the symptoms were more prevalent in smokers than in nonsmokers. Nonsmokers with both long- and short-term work exposure had higher prevalences of dyspnea and rhinitis than control workers. Smokers exposed for 10 years or less had significantly higher prevalences of chronic phlegm than nonsmokers with the same duration of exposure ( $p < 0.05$ ). In workers exposed for >10 years, there were significantly higher prevalences of chronic cough, chronic phlegm, and chronic bronchitis in smokers than in nonsmokers ( $p < 0.01$ ). A high prevalence of shift-related symptoms was found in exposed workers. Significant across-shift reductions of ventilatory capacity tests were documented in this cohort and varied from an average of 4.0% for FVC to 14.2% for FEF<sub>25</sub>. Preshift values of ventilatory capacity were significantly lower in this exposed population compared to predicted values suggesting a chronic effect. Our data suggest that textile dyeing workers develop acute and chronic respiratory impairment as a result of their exposures. These findings are exacerbated by cigarette smoking. Am. J. Ind. Med. 31:344-352, 1997. © 1997 Wiley-Liss, Inc.*

**KEY WORDS:** textile dyeing workers; respiratory symptoms; ventilatory capacity

## INTRODUCTION

There are numerous publications on the effect of dust on the respiratory system of textile workers employed in processing textile fibers such as cotton [Beck et al., 1982; Witek et al., 1988; Zuskin et al., 1991, 1992], hemp [Bouhuys and Zuskin, 1976; Zuskin et al., 1990, 1992], flax [Valic and Zuskin, 1972], and wool [Zuskin et al., 1976,

1995; Lowe et al., 1988; Schachter et al., 1992]. However, there are few available data on respiratory function in the workers employed in the textile dyeing industry.

Work-related respiratory symptoms among employees in wool dye-houses in the United Kingdom associated with exposure to Lanazol dyes were reported by Topping et al. [1989]. Viegi et al. [1985] evaluated respiratory function in workers of a dye factory and found the prevalence of chronic bronchitis and dyspnea of 32%; flow rates were significantly lower than reference values. Among their workers, 71% had diagnoses of chronic obstructive lung disease; they all worked >15 years in the dye textile industry.

Nine cases of immediate type occupational asthma due to reactive dyes in one dye industry were described by Park et al. [1989]. Docker et al. [1987] showed that >15% of

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workers handling reactive dyes had work-related respiratory or nasal symptoms. The same authors considered that the symptoms could be attributed to an irritant response to chemicals used in this industry, including hydrochloric acid vapor, sulfur dioxide, as well as the reactive dyes themselves. Some of the symptoms were attributed to an allergic reaction to specific agents in the reactive dyes. Recently, Lin et al. [1995] found that reactive dye workers with atopy or asthma were at a significantly higher risk of developing respiratory symptoms. Alanko et al. [1978] reported four cases of immediate-type occupational allergy (asthma and rhinitis) to reactive dyes. According to these authors, reactive dyes probably act as haptens. Interestingly, Park et al. [1990] described that reactive dye induced occupational asthma without nonspecific bronchial hyperreactivity.

In the present study, we evaluated respiratory symptoms in a group of textile dyeing workers employed in three cotton and wool processing textile plants in Croatia.

## MATERIALS AND METHODS

### Dyeing Process

Textile workers were employed in dyeing textile fibers obtained as the final product after carding and spinning. The dyeing was performed in several large open vats located in areas completely separated from the carding and spinning machines. The cotton and wool fibers were first sorted by type and quality (usually <1 hour per shift) and then manually placed into vats and boiled for different periods of time (usually several hours). There was no actual processing of textile fibers such as occurs in textile mills. Hence the dust found in this industry is not "textile" dust.

The dyeing process used different types of commercially available azo and reactive dyes in addition to many other chemical agents. The dyeing process was performed at a temperature of 60°C to 70°C. The different types of dyes included: direct dyes (sulfonated azo compounds); reductive dyes (indigo and indigo disodium salts, or anthraquinone derivate); disperse dyes (azo and anthraquinone structure of low molecular weight); naphthol dyes (azo with azochromophorm components); reactive dyes (azo and anthraquinone derivate-Cibakon E, Cibakon F); cation dyes (diphenylmethane derivate, triphenylmethane derivate, or triazine colors); sulfur dyes (sulfur compounds); and acetic dyes (sodium salt of organic acids). Some of these dyes were purchased from Ciba (Switzerland) and some were produced by the local chemical industry in Zagreb (Croatia).

Before dyeing, the fibers are treated with acetic acid (CH<sub>3</sub>COOH), formic acid (HCOOH), sodium hydroxide (NaOH), sodium hydrosulfide (NaHS), potassium bicarbonate (KHCO<sub>3</sub>), chromium salt, or formaldehyde (HCHO). During the dyeing process, fibers are placed into

the large vats along with the dyes and other ingredients and are stirred in a partly open system. At high temperatures present in the vats, vapors of different agents are released, including hydrogen sulfide (H<sub>2</sub>S) and sulfur dioxide (SO<sub>2</sub>) (when sulfur dyes are used), nitrogen oxides (when azo dyes are used), anilin (when oxidant dyes are used), acetic acid and formic acid (when acetic dyes are used), as well as other vapors released from the dyes, which may be found in the workplace atmosphere and inhaled by exposed workers.

In addition to the vapors and fumes associated with the dyeing process, these workers were exposed to high temperatures and to a high relative humidity.

### Environmental Measurement

In addition to the mandated yearly inspections, environmental measurements were carried out at workplaces where tested workers were employed. Measurements included determination of fumes and gases (e.g., H<sub>2</sub>S, H<sub>2</sub>SO<sub>4</sub>, NaOH) by Drager indicator tubes and expressed in ppm or mg/m<sup>3</sup>. Total and respirable dust samples were collected by a Hexhlet, two-stage sampling apparatus. Temperature was measured by psychrometer "Asmanu," relative humidity by digital hygrometer, and air flow by apparatus "Testo-term" type 491. At least three measurements for each parameter were performed at workplaces where workers were examined. In this plant, exposures to the various substances occur concurrently. All subjects were exposed to approximately the same concentrations of agents. Peak exposures were not measured separately. Furthermore, it was not possible to separately measure concentrations of azo or reactive dyes because they are in use simultaneously and reactive processes preclude separation. Samplings were performed through the entire 8-hour work shift at each vat at five locations on 3 separate days. No significant variations in measurement were noted.

### Subjects

This study included a group of 97 male and 38 female textile workers. A group of 76 male and 27 female nonexposed workers employed as packers of food products in the food industry was studied as a control for the prevalence of chronic respiratory symptoms. Age, duration of employment, and smoking habits were similar in the exposed and control groups (Table I).

The issue of healthy worker effect in this population was attenuated by special circumstances. Usually this effect tends to reduce the measured severity of disease in a worker population. Because of the economic crisis in Croatia due to the war, workers have tended to stay on the job in spite of health problems; affected workers simply cannot find work elsewhere.

**TABLE I.** Demographic and Other Data in 135 Textile Dyeing Workers and in a Control Group, Croatia 1993

Sex	Group	Mean age (yrs)	Mean height (cm)	Mean employment (yrs)	Smoking habit
Male	Exposed N = 97	40 ± 9	172 ± 10	18 ± 9	58 (59.8%)
	Control N = 76	39 ± 8	173 ± 12	16 ± 7	44 (57.9%)
Female	Exposed N = 38	40 ± 7	161 ± 11	18 ± 7	4 (10.5%)
	Control N = 27	38 ± 7	162 ± 12	16 ± 9	3 (11.1%)

## Respiratory Symptoms

Chronic respiratory symptoms were recorded by using the British Medical Research Council questionnaire on respiratory symptoms (1960) with additional questions on occupational asthma [WHO, 1986; Maestrelli et al., 1992]. The questionnaire was administered by the investigators performing the epidemiologic study. In all workers a detailed occupational history as well as questions about their smoking habit were recorded. The following definitions were used:

Chronic cough or phlegm: cough and/or phlegm to a minimum of 3 months a year.

Chronic bronchitis: cough and phlegm for a minimum of 3 months a year and for not less than 2 successive years.

Dyspnea grades: 3—shortness of breath when walking with other people at an ordinary pace on level ground; 4—shortness of breath when walking at their own pace on level ground.

Occupational asthma: recurring attacks of dyspnea, chest tightness, and pulmonary function impairment of the obstructive type diagnosed by physical examination and spirometric measurements during exposure to dust at or following work (decrease in FEV<sub>1</sub> >15%) and confirmed by the medical records. These medical records are kept at the Institute for Occupational Disease in Zagreb. No workers came into the industry with asthma since this is a reason for pre-employment exclusion.

Acute symptoms that developed during the work shift were also recorded in all textile dyeing workers. Symptoms comprised cough, dyspnea, irritation or dryness of the

throat, secretion, dryness or bleeding of the nose, eye irritation, and headache.

## Ventilatory Capacity

Ventilatory capacity measurements were performed by recording the maximum expiratory flow-volume (MEFV) curves on spirometer Pneumoscreen (Jaeger, Wurzburg, Germany). On MEFV curves the forced vital capacity (FVC), 1-second forced expiratory volume (FEV<sub>1</sub>), and maximum flow rates at 50% and the last 25% of the vital capacity (FEF<sub>50</sub>, FEF<sub>25</sub>) were read. All measurements were performed before (6 a.m.) and after the morning shift (2 p.m.). At least three MEFV curves were recorded for each subject, and the best value was used as the result of the test [Quanjer, 1993]. Calibration was performed on a daily basis. The measured values of ventilatory capacity were compared with the predicted normal values of Quanjer [1983].

## Statistical Analysis

The results of ventilatory capacity measurements in textile dyeing workers (comparison of baseline to predicted values) were analyzed by using the paired t-test. The Chi-square test or when appropriate Fisher's exact test was used for testing differences in the prevalence of respiratory symptoms.  $p < 0.05$  was considered statistically significant. We did not make any adjustment for the multiple comparisons in these analyses.

## RESULTS

### Respiratory Symptoms

Table II presents the prevalences of chronic respiratory symptoms for male and female textile dyeing workers and for the control group. For the male dyeing workers, there were significantly higher prevalences of all chronic respiratory symptoms compared to the control workers ( $p < 0.01$  or  $p < 0.02$ ). For the female dyeing workers, the differences were significant for dyspnea, rhinitis, sinusitis and hoarseness ( $p < 0.01$ ). Eight cases of occupational asthma were found among the textile dyeing workers (8/135; 5.9%) compared to none among the controls ( $p < 0.02$ ).

In Table III, we examine the presence of chronic respiratory symptoms in the male control group by smoking habit. No significant differences were noted between smokers and nonsmokers.

Table IV presents the prevalence of chronic respiratory symptoms in male dyeing workers by their smoking habit and by the duration of their exposure (<10 years and >10

**TABLE II.** Prevalence of Chronic Respiratory Symptoms in Textile Dyeing and Control Workers, Croatia 1993

Sex	Group	Mean <sup>a</sup>	Mean <sup>a</sup>	Chronic cough	Chronic phlegm	Chronic bronchitis	Occupational asthma	Dyspnea	Rhinitis	Sinusitis	Hoarseness
		age (yrs)	employment (yrs)					grade 3 & 4			
Male	Exposed N = 97	40 ± 9	18 ± 9	43 44.3%	35 36.1%	34 35.1%	7 7.2%	56 57.7%	34 35.1%	36 37.1%	37 38.1%
	Control N = 76	39 ± 8	16 ± 7	14 18.4%	11 11.5%	10 13.2%	0 0%	3 3.9%	2 2.6%	0 0%	0 0%
Female	Exposed N = 38	40 ± 7	18 ± 7	8 21.1%	6 15.8%	6 15.8%	1 2.6%	29 76.3%	17 44.7%	16 42.1%	15 39.5%
	Control N = 27	38 ± 7	16 ± 9	2 7.4%	1 3.7%	1 3.7%	0 0%	0 0%	0 0%	0 0%	0 0%

<sup>a</sup>Presented as mean ± SD.

NS = difference statistically not significant ( $p > 0.05$ ).

**TABLE III.** Prevalence of Chronic Respiratory Symptoms in Male Food Packing (control) Workers by Smoking Habit, Croatia 1993

Group	Chronic cough	Chronic phlegm	Chronic bronchitis	Occupational asthma	Dyspnea	Rhinitis	Sinusitis	Hoarseness
Smokers N = 44	12 15.8%	10 13.2%	9 11.8%	0 0%	2 4.5%	2 4.5%	0 0%	0 0%
	NS	NS	NS	NS	NS	NS	NS	NS
Nonsmokers	2 6.3%	1 3.1%	1 3.1%	0 0%	1 3.1%	0 0%	0 0%	0 0%

NS = not significant.

years). Female dyeing workers were primarily nonsmokers (34/38; 89.5%) and the data are presented for nonsmokers only by duration of exposure. After both short- and long-term exposures, nonsmoking dyeing workers (primarily women) had significantly greater prevalences of dyspnea and rhinitis ( $p < 0.01$ ) than controls. There was a significantly higher prevalence of chronic phlegm in smokers than in nonsmokers exposed for 10 years or less ( $p < 0.05$ ). Smokers exposed for >10 years had significantly higher prevalences of chronic cough, chronic phlegm, and chronic bronchitis than nonsmokers with the same exposure ( $p < 0.01$ ).

Table V presents the prevalence of acute symptoms in textile dyeing workers by smoking habit and duration of exposure. No significant differences were found between male smokers and nonsmokers nor between those with shorter and longer exposures. For female workers, the data are presented only for nonsmokers; no significant differences were noted for these symptoms by duration of

exposure. There was also no difference for the prevalence of acute symptoms between male and female workers.

### Ventilatory Capacity

Table VI shows the measured and predicted ventilatory capacity data in male and female textile dyeing workers. There were significant across-shift reductions for all parameters in male textile dyeing workers and for FEF<sub>50</sub> and FEF<sub>25</sub> in female textile dyeing workers ( $p < 0.05$ ). The mean across-shift reductions varied from 5.1% for FVC to 12.4% for FEF<sub>25</sub>. Across-shift changes for workers with occupational asthma were slightly greater than those of healthy workers (for occupational, asthma-across shift changes were: FVC = 6.7–10.2%; FEV<sub>1</sub> = 9.8–15.6%; FEF<sub>50</sub> = 11.5–21.6%; FEF<sub>25</sub> = 16.5–27.2%). Comparison of pre-shift measurements with predicted values demonstrated significantly lower values for all tests in male workers and for FEF<sub>50</sub> and FEF<sub>25</sub> in female workers ( $p < 0.05$ ). The mean

**TABLE IV.** Prevalence of Chronic Respiratory Symptoms in Textile Dyeing Workers by Smoking Habit and Duration of Exposure, Croatia 1993

Sex	Smoking habit	Exposure (yrs)	N	Chronic cough	Chronic phlegm	Chronic bronchitis	Occupational asthma	Dyspnea	Rhinitis	Sinusitis	Hoarseness
Male	Smokers	≤10	15	7	6	6	0	8	6	6	4
				46.7%	40.0%	40.0%	0%	53.3%	40.0%	40.0%	26.7%
				NS	<0.05	NS	NS	NS	NS	NS	NS
	Nonsmokers	≤10	8	1	0	0	0	3	1	0	1
12.5%				0%	0%	0%	37.5%	12.5%	0%	12.5%	
Male	Smokers	>10	43	29	26	25	5	25	19	21	21
				67.4%	60.5%	58.1%	11.6%	58.1%	44.2%	48.8%	48.8%
				<0.01	<0.01	<0.01	NS	NS	NS	NS	NS
	Nonsmokers	>10	31	6	3	3	2	20	8	9	11
19.4%				9.7%	9.7%	6.5%	64.7%	25.8%	29.0%	35.5%	
Female	Nonsmokers <sup>a</sup>	≤10	5	1	1	1	0	3	2	2	1
				20.0%	20.0%	20.0%	0%	60.0%	40.0%	40.0%	20.0%
				NS	NS	NS	NS	NS	NS	NS	NS
	Nonsmokers <sup>a</sup>	>10	29	7	5	5	1	23	14	12	13
24.1%				17.2%	17.2%	3.4%	79.3%	48.3%	41.4%	44.8%	

<sup>a</sup>Because of small numbers of female smokers, data are presented only for female nonsmokers.  
NS = difference statistically not significant (p > 0.05).

**TABLE V.** Prevalence of Acute Symptoms in Textile Dyeing Workers by Smoking Habit and Duration of Exposure, Croatia 1993

Sex	Smoking habit	Exposure (yrs)	N			Throat		Eye	Nose			Headache
				Cough	Dyspnea	Irritation	Dryness	irritation	Secretion	Dryness	Bleeding	
Male	Smokers	≤10	15	9	11	10	11	11	2	9	4	7
				60.0%	73.3%	66.7%	73.3%	73.3%	13.3%	60.0%	26.7%	46.7%
				NS	NS	NS	NS	NS	NS	NS	NS	
	Nonsmokers	>10	43	28	28	29	32	29	7	28	13	17
65.1%				65.1%	67.4%	74.4%	67.4%	16.3%	65.1%	30.2%	39.5%	
Female	Nonsmokers <sup>a</sup>	≤10	8	4	5	3	3	3	3	3	2	3
				50.0%	62.5%	37.5%	37.5%	37.5%	37.5%	37.5%	25.0%	37.5%
				NS	NS	NS	NS	NS	NS	NS	NS	
	Nonsmokers <sup>a</sup>	>10	31	16	17	18	20	22	9	16	7	14
51.6%				54.8%	58.1%	64.5%	71.0%	29.0%	51.6%	22.6%	45.2%	
Female	Nonsmokers <sup>a</sup>	≤10	5	3	3	3	3	5	0	3	1	3
				60.0%	60.0%	60.0%	60.0%	80.0%	0%	60.0%	20.0%	60.0%
				NS	NS	NS	NS	NS	NS	NS	NS	
	Nonsmokers <sup>a</sup>	>10	29	22	22	21	20	23	8	19	10	21
75.9%				72.4%	72.4%	68.9%	79.3%	27.6%	65.5%	34.5%	72.4%	

<sup>a</sup>Because of small numbers of female smokers, data are presented only for female nonsmokers.  
NS = difference statistically not significant (p > 0.05).

percentage of predicted values in male workers varied from 94.7% for FVC to 82.4% for FEF<sub>25</sub> and in female from 98.8% for FVC to 80.4% for FEF<sub>25</sub>. Analysis of the individual measured ventilatory capacity data in exposed

workers as a percentage of predicted demonstrated that values below 70% of predicted FVC were found in 10.3% of male and 7.9% of female workers, for FEV<sub>1</sub> in 15.5% of male and 10.5% of female workers, for FEF<sub>50</sub> in 17.5% of

TABLE VI. Ventilatory Capacity and Across-Shift Changes in Textile Dyeing Workers, Croatia 1993\*

Sex	FVC			FEV <sub>1</sub>			FEF <sub>50</sub>			FEF <sub>25</sub>		
	Before shift	Difference before/after shift		Before shift	Difference before/after shift		Before shift	Difference before/after shift		Before shift	Difference before/after shift	
		L	%		P	L		%	P		L/s	%
Male N = 97	4.28 ± 0.83 <0.05	-5.1%	<0.05	3.51 ± 0.65 <0.05	-6.0%	<0.05	4.92 ± 1.00 <0.05	-6.9%	<0.05	2.10 ± 0.79 <0.05	-12.4%	<0.05
Female N = 38	4.52 ± 0.47 <sup>a</sup> NS	-6.3%	NS	3.74 ± 0.41 <sup>a</sup> NS	-6.3%	NS	5.23 ± 0.39 <sup>a</sup> <0.05	-8.9%	<0.05	2.55 ± 0.31 <sup>a</sup> <0.05	-7.2%	<0.05
	3.16 ± 0.64 3.20 ± 0.47 <sup>a</sup>			2.72 ± 0.50 2.76 ± 0.33 <sup>a</sup>			4.12 ± 0.84 4.49 ± 0.40 <sup>a</sup>			1.81 ± 0.64 2.25 ± 0.29 <sup>a</sup>		

\*Data are presented as mean ± SD.

<sup>a</sup>Predicted values [Quanjer, 1983].

NS = difference statistically not significant (p &gt; 0.05).

TABLE VII. Ventilatory Capacity and Across-Shift Changes in Male Textile Dyeing Workers by Smoking Habit and Duration of Exposure, Croatia 1993\*

Smoking habit	Exposure (yrs)	N	FVC			FEV <sub>1</sub>			FEF <sub>50</sub>			FEF <sub>25</sub>		
			Before shift	Difference before/after shift		Before shift	Difference before/after shift		Before shift	Difference before/after shift		Before shift	Difference before/after shift	
				L	%		P	L		%	P		L/s	%
Smokers N = 58	≤10	15	4.81 ± 0.76 NS	-5.4	NS	3.84 ± 0.76 <0.05	-5.7	NS	5.38 ± 1.42 NS	-4.6	NS	2.47 ± 0.64 <0.05	-14.2	<0.05
			5.02 ± 0.37 <sup>a</sup>			4.20 ± 0.31 <sup>a</sup>			5.46 ± 0.39 <sup>a</sup>			2.88 ± 0.24 <sup>a</sup>		
	>10	43	4.24 ± 0.86 NS	-5.2	NS	3.41 ± 0.68 <0.01	-5.6	NS	4.85 ± 1.41 NS	-6.4	NS	2.04 ± 0.83 <0.05	-10.8	<0.05
Nonsmokers N = 39	≤10	8	4.73 ± 0.89 NS	-4.0	NS	3.78 ± 0.50 NS	-6.6	NS	5.33 ± 1.23 NS	-5.2	NS	2.45 ± 0.62 NS	-9.8	NS
			4.94 ± 0.57			4.15 ± 0.43			5.62 ± 0.38 <sup>a</sup>			2.64 ± 0.26 <sup>a</sup>		
	>10	43	3.95 ± 0.62 <0.05	-4.6	NS	3.42 ± 0.49 NS	-6.4	NS	4.68 ± 1.57 <0.05	-9.6	NS	1.92 ± 0.80 <0.01	-13.5	<0.05
			4.25 ± 0.56 <sup>a</sup>			3.49 ± 0.25 <sup>a</sup>			5.39 ± 0.24 <sup>a</sup>			2.60 ± 0.20 <sup>a</sup>		

\*Data are presented as mean ± SD.

<sup>a</sup>Predicted values [Quanjer, 1983].

NS = difference statistically not significant (p &gt; 0.05).

male and 13.2% of female workers, and for FEF<sub>25</sub> in 20.6% of male and of 18.4% of female workers.

Table VII presents ventilatory capacity measurements in male workers by smoking and duration of exposure (<10 years, >10 years). There were significant differences between preshift and predicted values for smokers after both

short and long exposures for FEV<sub>1</sub> and FEF<sub>25</sub>, and in nonsmokers with longer exposures (>10 years) for FVC, FEF<sub>50</sub> and FEF<sub>25</sub>.

Table VIII shows the ventilatory capacity data in female nonsmoking textile dyeing workers by the duration of exposure (<10 years, >10 years). Women workers had

**TABLE VIII.** Ventilatory Capacity and Across-Shift Changes in Female Nonsmoking Textile Dyeing Workers by Duration of Exposure, Croatia 1993\*

Exposure (yrs)	N	FVC			FEV <sub>1</sub>			FEF <sub>50</sub>			FEF <sub>25</sub>		
		Before shift		Difference before/after shift	Before shift		Difference before/after shift	Before shift		Difference before/after shift	Before shift		Difference before/after shift
		L	%		P	L		%	P		L/s	%	
≤10	5	3.29 ± 0.75	-7.3	NS	2.85 ± 0.74	-4.0	NS	4.24 ± 1.30	-3.1	NS	1.92 ± 1.07	-5.0	NS
		NS			NS			<0.05			<0.05		
		3.58 ± 0.27 <sup>a</sup>			3.03 ± 0.25 <sup>a</sup>			4.46 ± 0.21 <sup>a</sup>			2.40 ± 0.13 <sup>a</sup>		
>10	29	3.00 ± 0.56	-5.7	NS	2.62 ± 0.42	-5.7	NS	4.08 ± 0.85	-8.7	NS	1.77 ± 0.57	-6.3	NS
		NS			NS			<0.05			<0.05		
		3.16 ± 0.30 <sup>a</sup>			2.72 ± 0.29 <sup>a</sup>			4.49 ± 0.23 <sup>a</sup>			2.20 ± 0.18 <sup>a</sup>		

\*Because of small numbers of smokers, data are presented only for nonsmokers. Data are presented as mean ± SD.

<sup>a</sup>Predicted values [Quanjer, 1983].

NS = difference statistically not significant (p > 0.05).

**TABLE IX.** Mean Concentrations of Environmental Agents Measured in the Workplace in Study of Textile Dyeing Process, Croatia 1993\*

Agents	Concentrations			
	Measured		TLV <sup>a</sup>	
	mg/m <sup>3</sup>	ppm	mg/m <sup>3</sup>	ppm
Potassium bicarbonate (KHCO <sub>3</sub> )	0.3		2.0	
Hydrogen sulfide (H <sub>2</sub> S)	0.9		2.0	
Formaldehyde (HCHO)		0.1		0.5
Sodium hydroxide (NaOH)	3.1		2.0	
Acetic acid (CH <sub>3</sub> COOH)	3.2		25.0	
Hydrogen peroxide (H <sub>2</sub> O <sub>2</sub> )		2.1		1.0
Sulfuric acid (H <sub>2</sub> SO <sub>4</sub> )	0.5		1.0	
Ethylene glycol (CH <sub>2</sub> OHCH <sub>2</sub> OH)		150.0		50.0

\*Individual measurements of dye components was not feasible.

<sup>a</sup>Threshold limit value (maximum allowable concentrations).

significantly lower measured FEF<sub>50</sub> and FEF<sub>25</sub> than predicted values after both short- and long-term exposures.

### Environmental Measurements

The environmental measurements are presented in Table IX. These data demonstrate that, in general, the average measured gas and vapor values were within the limits established by Croatian standards (except for sodium hydroxide, hydrogen peroxide, and ethylene glycol). No textile dust is present as explained in the Materials and Methods section. However, respirable dust was measured at 0.7 to 2.1 mg/m<sup>3</sup>, whereas total dust concentrations varied from 1 to 4.0 mg/m<sup>3</sup>. The mean measured humidity in the

working environment varied from 40% to 67% (standard: 40% to 55%); environmental measured temperature varied from 22°C to 29°C (standard: 20°C to 23°C) and air flow varied from 0.03 m/s to 0.05 m/s (standard <0.3 m/s).

### DISCUSSION

Our data demonstrate that workers employed in textile dyeing industries may develop acute and chronic respiratory symptoms as well as changes in lung function. Prevalences of chronic respiratory symptoms in exposed workers were frequently (significantly) higher than in control workers. In the exposed workers, the highest prevalences of chronic symptoms were obtained for dyspnea, chronic cough, chronic phlegm, rhinitis, sinusitis, and hoarseness, and the frequency of these symptoms increased (but not significantly) with the duration of exposure.

In the textile dyeing workers we studied, there was also a high prevalence of acute symptoms particularly upper respiratory irritation, which developed during the work shift, being greatest for dryness of the throat and eye irritation. Upper respiratory and eye symptoms have frequently been documented in work environments using dyes. Molhave et al. [1986] described acute symptoms such as irritation of the eyes, nose, and throat in experimental exposures to low concentrations of volatile organic compounds (organic gases and vapors). This effect was acute and showed no signs of adaptation. Docker et al. [1987] reported that >15% of workers handling reactive dyes had work-related respiratory or nasal symptoms. These authors suggested that such symptoms could be attributed to an irritant response associated with a variety of chemicals, including hydrochloric acid vapors, sulfur dioxide, and reactive dyes. The same authors reported that two patterns of allergic lower respiratory

symptoms might occur; an immediate response of short duration and a longer lasting response, usually of several hours' duration, sometimes accompanied by nocturnal asthma. In their study, allergic symptoms were strongly associated with specific IgE levels. These findings appear to correspond to our documentation of a higher prevalence of occupational asthma.

In a study by Park et al. [1991], 25.2% of reactive-dye exposed workers had work-related lower respiratory symptoms associated with or without nasal, skin, or eye symptoms. Specific IgE was detected more frequently in symptomatic employees (30%). The findings of these authors suggested that reactive dyes could induce an IgE mediated immunological response. The prevalences were similar in men and women textile workers. Kalas and Runstukova [1980] described sensitization to ostazine dyes in 27% of textile workers. Occupational asthma was diagnosed in 7.5% of their exposed workers, a prevalence that is similar to that seen in our exposed workers (male: 7.2%). In a study by Kalas and Runstukova [1982] involving ostazine dye workers, symptoms were characterized by vasomotor rhinitis, allergic conjunctivitis, cough, wheezing, and dyspnea. Sensitization developed in the first year of employment. In these workers, those with positive intradermal tests also had positive bronchoprovocation tests to dyes. The same authors found chronic bronchitis present in 69.2% of workers. The frequency of chronic bronchitis in our exposed workers was considerably lower (female: 15.8%; male: 35.1%). Hagmar et al. [1986] reported a case of type-1 allergic sensitization to reactive dye. Similarly, Quirce et al. [1994] suggested that natural dyes may induce immunologic responses, most likely IgE mediated, in workers with symptoms of occupational asthma.

Lung function testing in our workers demonstrated significant across-shift reductions varying from  $-5.1\%$  to  $-12.4\%$  depending on the parameter measured. Lung function measured in workers in related industries show similar results. For example, these data resemble those of Angerer et al. [1991] who reported across-shift reductions in FEV<sub>1</sub> for floor laying workers exposed to mixtures of organic solvents. These functional changes were accompanied by breathlessness and coughing. Significant across-shift reductions due to the irritant effects of acids in vegetable pickling and mustard workers have been reported by Zuskin et al. [1993]. Blanc et al. [1993] described persistent increased nonspecific airway responsiveness accompanied by respiratory symptoms in workers following the inhalation of irritant chemicals.

Comparison of preshift with predicted values in our studied workers demonstrated significant decreases in all ventilatory capacity tests in males and in FEF<sub>50</sub> and FEF<sub>25</sub> for female workers. These preshift changes suggest a chronic effect on lung function following these exposures. A progression in lung function abnormalities was suggested

particularly among nonsmokers (Table VI). Among nonsmokers those with short length of employment ( $<10$  years) had no significant differences when compared to controls, whereas workers employed for  $>10$  years had significantly lower FVC, FEF<sub>50</sub>, and FEF<sub>25</sub>.

For centuries, work in the textile industry has been recognized as a potential hazard to worker health. Our study suggests that, in addition to textile dust, a number of chemical products used in the dyeing of textiles may cause airway disease. This separate hazard deserves further characterization and medical surveillance to protect worker safety.

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