Tohoku J. Exp. Med., 2005, **207**, 157-163

Determination of Formaldehyde Levels in 100 Furniture Workshops in Ankara

Songül Acar Vaizoğlu,[1] Sefer Aycan,[2] Levent Akin,[1] Pelin Koçdor,[1] Gül Pamukçu,[1] Orkun Muhsinoğlu,[1] Feyza Özer,[1] E. Didem Evci[3] and Çağatay Güler[1]

[1]*Department of Public Health, Hacettepe University, Ankara, Turkey*
[2]*Department of Public Health, Gazi University, Ankara, Turkey, and*
[3]*Department of Public Health, Adnan Menderes University, Aydın, Turkey*

Vaizoğlu, S.A., Aycan, S., Akin, L., Koçdor, P., Pamukçu, G., Muhsinoğlu, O., Özer, F., Evci, E.D. and Güler, Ç. *Determination of Formaldehyde Levels in 100 Furniture Workshops in Ankara*. Tohoku J. Exp. Med., 2005, **207** (2), 157-163 —— One of the airborne pollutants in wood products industry is formaldehyde, which may pose some health effects. Therefore this study is conducted to determine formaldehyde levels in 100 furniture-manufacturing workshops in Ankara and also to determine the symptoms, which may be related with formaldehyde exposure among the workers. Indoor formaldehyde levels ranged from 0.02 ppm to 2.22 ppm with a mean of 0.6 ± 0.3 ppm. Outdoor formaldehyde levels also ranged from 0.0 ppm to 0.08 ppm with a mean of 0.03 ± 0.03 ppm. Formaldehyde levels were higher in workplaces located at basement than in workplaces located at or above ground level ($p < 0.01$). An association was found between indoor formaldehyde levels and the types of fuel used ($p < 0.05$). The levels were higher in workplaces where only sawdust was used for heating, than in workplaces where wood, coal, and sawdust are used ($p = 0.02$). An association was found between runny nose and indoor formaldehyde levels ($p = 0.03$). Formaldehyde levels were lower in workplaces where employees had no symptoms than in those where employees had 4 or more symptoms ($p = 0.02$). Of 229 employees 57 subjects (24.9%) work under the formaldehyde levels of 0.75 ppm and above. Thus, approximately one fourth of the employees in workplaces are working in environments with formaldehyde levels exceeding those permitted by Occupational Safety and Health Administration (OSHA). The employees working in small-scale furniture workshops are at risk of formaldehyde exposure. Measures, such as improved ventilation, have to be taken in these workplaces, in order to decrease the formaldehyde levels.
——— formaldehyde; wood furniture workshops; symptoms

Health in the workplace is affected by some airborne pollutants such as formaldehyde in the work environment (La Dau 1997; Wallace 1998). Many studies have been conducted on health effects of formaldehyde. When it occurs in the air at higher levels than normal, it affects eyes and upper airways and may trigger asthma attacks in asthmatics and cause tearing and a burning

Received May 27, 2005 revision accepted for publication July 28, 2005.
Correspondence: Dr. Songül Acar Vaızoğlu, Hacettepe Üniversitesi, Tıp Fakültesi, Halk Sağlığı AD., 06100, Samanpazarı-Ankara, Turkey.
e-mail: sacar@hacettepe.edu.tr

sensation in the eyes, nose, and throat (Bardana and Montanara 1991; Wallace 1998; Backman and Haghighat 1999; Yang et al. 2001). It has also been reported to lead to shortness of breath, asthmatic symptoms and skin eruptions at concentrations over 0.1 ppm in some people (Krzyzanowski et al. 1990; Norback et al. 1995; Rumchev et al. 2002). International Agency for on Cancer (IARC) has classified formaldehyde as Group 2A carcinogen. According to the report, "the results of the study of industrial workers in the USA," provided sufficient epidemiological evidence that formaldehyde causes nasopharyngeal cancer in humans. There is strong but not sufficient evidence for a causal association between leukemia and occupational exposure to formaldehyde. There is only limited epidemiological evidence on sino-nasal cancer and formaldehyde exposure in humans. There is not sufficient epidemiological evidence on causal relation between formaldehyde and other cancers" (IARC web site 2004).

The Occupational Safety and Health Administration (OSHA) gives the permissible exposure limit as 0.75 parts formaldehyde per million parts of air (0.75 ppm) in wood products industry (OSHA web site 2004). It is shown that formaldehyde exposure may, depending on the dosage, cause cancer in the upper respiratory tract in some laboratory animals (Swenberg et al. 1980; Wantke et al. 1996). Cancer-related deaths in a group of 26,561 employees exposed to formaldehyde were found 35% higher than the national cancer deaths. However, it was pointed out that these employees had also been exposed to phenol, melamine, urea, and sawdust (Liebling et al. 1984). If ambient formaldehyde levels exceed 0.01 ppm, some measures have to be taken. The most important measure is improving the ventilation (Enviromental Protection Agency web site 2001; States of California web site 2001).

Since wood products industry is one of the important occupational formaldehyde exposure media, in the present study, we planned to measure formaldehyde levels in 100 furniture-manufacturing workshops, and to determine some possible health effects among the employees working in these workshops.

Materials and Methods

In this descriptive study formaldehyde levels were measured in 100 workplaces and a questionnaire form was applied to the employees who accepted to participate.

A questionnaire form comprising 33 questions was used by face-to-face interview. In these work places 248 persons were working and 229 of them accepted to participate (92.3%). There were questions about the work place and the work (age, floor of the building, heating and ventilation system, the type of fuel being used for heating, the materials used in manufacturing etc.), and also about the workers (age, sex, duration of working in these sector and some symptoms observed since working in this sector and chronical diseases) in the questionnaire (Note: For the questionnaire form please contact with the responsible author. e-mail: sacar@hacettepe.edu.tr)

A Formaldemeter 400 was used to determine formaldehyde levels; those used this apparatus had a standard training for its use. PPM Formaldemeter 400 was produced by PPM Technology Limited, Bangor, Gwynedd, LL57 4BL, United Kingdom. The detection rate of the instrument was 0.05-10 ppm and the sensitivity of measurement was 95% (Operation Manual 2000). After every 50 measurements the calibration of the instrument was made and it was controlled.

Spot measurements were made in the center of each workplace. Outdoor formaldehyde measurements were made in the beginning, middle and end of each street. The mean of three measurements is used as outdoor formaldehyde level. Data are shown as mean ± S.D. Data was analyzed using SPSS 11.0 statistical software. Frequencies, percent distribution, χ^2 and graphics were done by SPSS 11.0 (SPSS Base User's Guide 2001).

The relevant institutional committee of Hacettepe University has approved this study.

Results

One of the occupations, which are under the risk of formaldehyde exposure, is wood products industry where glue, fiberboard, medium density fiber board (MDF) and other wood products are used. Formaldehyde levels were determined in 100 small-scale furniture-manufacturing workshops in Ankara. Seventy-seven (77%) of the workplaces were at ground level or higher, and all (100%) of the buildings were made of reinforced concrete. None of the workplaces used any form of ventilation other than fans and natural ventilation (windows and doors). Some workplaces were not ventilated on a daily basis, while others were ventilated for up to 8 eight hours a day. Glue was used in manufacturing in 99 (99%) of these workplaces, fiberboard in 95 (95%), MDF in 88 (88%), wood in 82 (82%), and plywood in 39 (39%). Cigarettes were smoked in 77 (77%) of the workplaces.

The distribution of formaldehyde levels outside and inside of the workplaces is shown in Table 1. Outdoor and indoor formaldehyde levels ranged from 0.00 to 0.08 ppm (0.03 ± 0.03 ppm) and 0.02 ppm to 2.22 ppm (0.6 ± 0.3 ppm) respectively. Among 89 (89%) of the workshops the outdoor formaldehyde levels were 0.02 ppm or higher. In 2 (2%) of the workshops indoor formaldehyde levels were below 0.1 ppm, while in 24 (24%) workshops formaldehyde levels were above the 8-hour exposure limit of 0.75 ppm permitted by OSHA (OSHA web site 2004).

The association between workplace formaldehyde levels and the floor, heating type of the workplace were assessed. Indoor formaldehyde levels were above 0.75 ppm, in 14 (18.2%) of the workplaces located on the ground floor or higher floors and in 10 (43.5%) of workplaces located in basements. Indoor formaldehyde levels were statistically higher in workplaces located in base-

TABLE 1. *The distribution of formaldehyde levels outside and inside the workplaces included in this study, Ankara, 2001 (n = 100)*

Formaldehyde levels (ppm)		*n*	(%)
Outdoor	< 0.02	11	11.0
	≧ 0.02	89	89.0
Mean of outdoor FA levels = 0.03 ± 0.03 ppm			
Indoor	< 0.1*	2	2.0
	0.1-0.74	74	74.0
	≧ 0.75**	24	24.0
Mean of indoor FA levels = 0.6 ± 0.3 ppm			

* Level at which symptoms occur (Backman and Haghighat 1999).
** Permitted 8-hour exposure limit (Backman and Haghighat 1999).

TABLE 2. *Distribution of indoor formaldehyde levels according to certain characteristics of the workplaces participating in the study, Ankara, 2001 (n = 100)*

Workplace characteristics		Indoor formaldehyde levels (ppm) < 0.75		≧ 0.75		*p*
		n	%*	*n*	%*	
Floor on which the workplace is located	Basement	13	56.5	10	43.5	
	Ground floor or higher	63	81.8	14	18.2	< 0.01
Type of heating	No heating	2	100.0	-	-	
	Sawdust	49	69.0	22	31.0	
	Wood/Coal/ Sawdust	25	92.6	2	7.4	< 0.05

* Row percentage given.

ments (Table 2) ($p < 0.01, \chi^2 = 6.2$). The formaldehyde levels of the two workplaces with no heating were below 0.75 ppm where in 31 (31%) of workplaces using only sawdust for heating were above 0.75 ppm. The mean formaldehyde level in workplaces using only sawdust for heating was higher than of the workplaces using wood, coal, and sawdust (Table 2) ($p < 0.05$, F = 4.05).

No statistically significant association was found between formaldehyde levels and the year of the building's construction, number of hours of ventilation per day, the presence of ventilation during measurement, the number of materials used in manufacturing furniture, or the smoking status of the workplace.

Two hundreds twenty nine employees working in these workplaces agreed to participate. Seventy-five (32.8%) of the participants were 35-44 years old, 7 (3.1%) were 17 or younger. One hundred fifty eight (69%) were graduated from primary school. Working duration in this sector ranged from 0.5 to 40 years (mean ± S.D. = 16.0 ± 9.4 years. All of the participants were male (Table 3).

No statistically significant association was found between workplace formaldehyde levels and the frequency of the occurrence of these symptoms: headache, tearing, throat dryness, cough, and dermatitis (Table 4). There was, however, a statistically significant association between indoor formaldehyde levels and the frequency of runny nose (Table 4).

There was a statistically significant differ-

TABLE 3. *Some socio-demographic characteristics of the employees, Ankara, 2001 (n = 229)*

Socio-demographic Characteristic		*n*	%
Age group	≦ 17	7	3.1
	18-24	47	20.5
	25-34	66	28.8
	35-44	75	32.8
	45 ≦	34	14.8
		Mean ± S.D. = 33 ± 10.0; min 15, max 68	
Education	Illiterate	1	0.4
	Literate (Not graduated from primary school)	4	1.7
	Primary	158	69.0
	Secondary	44	19.2
	High	21	9.2
	University	1	0.4
Working duration in this branch (year)	< 1	1	0.4
	1	1	0.4
	2-4	22	9.6
	5-9	35	14.3
	10-14	38	16.6
	≧ 15	132	57.6
		Mean ± S.D. = 16.0 ± 9.4; min 0.5, max 40	
Presence of a chronic disease diagnosed by a physician	Yes	39	17.0
	No	190	83.0

TABLE 4. *Some symptoms observed according to the FA levels in the work places, Ankara, 2001 (n = 229)*

Symptoms	Indoor FA Levels					
	< 0.75		≧ 0.75		χ^2	p
	n	%*	n	%*		
Headache (n = 108)	76	70.4	32	29.6	0.1	0.7
Tearing (n = 108)	76	70.4	32	29.6	0.1	0.7
Throat dryness (n = 75)	55	73.3	20	26.7	0.2	0.7
Runny nose (n = 46)	29	63.0	17	37.0	4.5	0.03
Cough (n = 64)	49	76.6	15	23.4	0.1	0.8
Dermatitis (n = 13)	10	76.9	3	23.1	0.02	0.9

* Row percentage given.

TABLE 5. *Mean number of symptoms in employees according to formaldehyde levels measured in workplaces included in the study, Ankara, 2001 (n = 229)*

Number of symptoms	Formaldehyde level (ppm) X ± Sx
0 (n = 107)	0.55 ± 0.03
1-3 (n = 74)	0.57 ± 0.04
≧ 4 (n = 48)	0.70 ± 0.05

F = 4.2, p = 0.016.

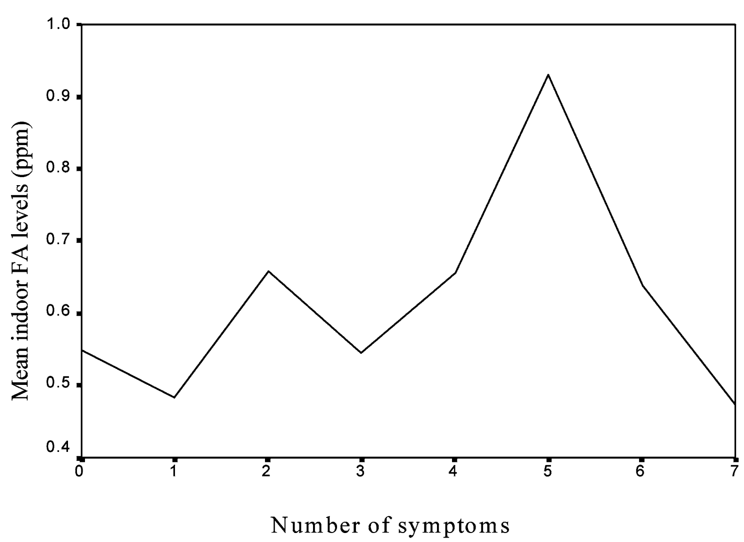

Fig. 1. Distribution of number of symptoms according to formaldehyde levels (FA) in the workplaces (Ankara, 2001).

ence between the mean formaldehyde levels of the workplaces where employees had no symptoms (0.55 ± 0.03 ppm) and those where employees had 4 or more symptoms (0.70 ± 0.05 ppm) (Table 5, Fig. 1).

Of the 229 employees participating in the study, 57 (24.9%) worked under formaldehyde levels of 0.75 ppm or higher.

Discussion

In the present study, the floor on which workplaces were located found to have a significant effect on indoor formaldehyde levels. Formaldehyde levels were higher in the basements. This may be related with insufficient ventilation of the basement floors.

Since the measurements were conducted in wintertime and there was no ventilation in most of these workplaces 79 (79%) during measurements, no statistically significant effect of ventilation per day on indoor formaldehyde levels was found. Participants stated that the ventilation systems were not activated as long as there was no visible dust. Mean indoor formaldehyde levels in workplaces with daily ventilation of 1 hour or more were lower than in workplaces with daily ventilation of less than 1 hour. These results suggest that ventilation may be effective in reducing indoor formaldehyde levels. In a study conducted in Egypt, mean formaldehyde levels were lower in the ventilated wood working shops (Abdel et al. 2000).

Spot formaldehyde measurements were performed in this study. In future studies using thirty minutes sampling or 24 hours' sampling methods and concomitant room temperature and air humidity measurements may be conducted in such workplaces (Endo et al. 2001)

The type of fuel used for heating was found to have a statistically significant effect on indoor formaldehyde levels. The use of sawdust of fiberboard and MDF alone may be a factor in the elevated formaldehyde levels. Increased use of wood and coal instead of sawdust for heating may be advisable or increasing the stuck efficacy may be helpful for the sawdust stoves.

Although there was cigarette smoking in 77 (77%) of the workplaces, no statistically significant effect of smoking status was observed on indoor formaldehyde levels. This may be related with the time of the measurements. The measurements were conducted in the final days of the month of Ramadan, when workplaces are closed before the time of the breaking of the fast, in nearly in all of the workplaces no cigarette was smoked.

Outdoor formaldehyde levels measured in the outdoor environments of the workplaces ranged from 0.00 to 0.08 ppm (mean = 0.03 ppm) (Table 1). In a study in which formaldehyde levels were measured in Ankara homes, the outdoor formaldehyde levels ranged from 0.00 to 0.11 ppm (mean = 0.006 ppm). The difference between these mean values may be because the present study was conducted in winter, and because the workplaces were located in an industrial zone where outdoor formaldehyde is high due to the materials used in the indoor environment.

A statistically significant correlation was found between number of symptoms and indoor formaldehyde levels. Mean indoor formaldehyde levels in workplaces where employees with 4 or more symptoms worked were significantly higher than those in workplaces where employees with no symptoms worked ($p = 0.01$). It appears that increases in formaldehyde levels may be accompanied by increases in symptoms; however, studies comparing symptoms and formaldehyde levels in greater detail are necessary. Employees indicated that these symptoms were more severe during their first years in this branch of employment, but that they decreased over time, as they get accustomed to the work environment. This suggests that employees in this branch may develop a formaldehyde tolerance.

In a study performed in the USA, it was found that 3.9% of 2,156,801 employees were exposed to formaldehyde levels of 0.75 ppm and above (OSHA web site 2004). In the present study, 57 (24.9%) of employees were found to be exposed to levels in excess of 0.75 ppm, and 25 (11%) of employees were working more than 8 hours in such workplaces. The small-scale workplaces and the lack of supervision in such places were not conducive to the prevention of indoor pollution.

It is recommended that measures should be taken to improve ventilation in the workplaces with high formaldehyde levels, as well as training of employees on the importance of ventilation. Such training was implemented in the workplaces where this study was carried out. Also the technical control of the small-scale workplaces should be carried out regularly. Symptoms such as tearing and runny nose were higher in employees in workplaces with high mean formaldehyde levels; therefore, similar studies should be carried out in workplaces with greater numbers of employees. Administration of the questionnaire in the absence of the employer is also recommended so that employees will answer the questions more reliable. Such studies should also be carried out in dry cleaners, the textile sector, and in the furniture manufacturing branches where painting and pressing are performed.

References

Abdel Hameed, A.A., Khoder, M.I. & Farag, S.A. (2000) Organic dust and gaseous contaminants at wood working shops. *J. Environ. Monit.*, **2**, 73-76.

Backman, H. & Haghighat, F. (1999) Indoor air quality and ocular discomfort. *J. Am. Oph. Asscoc.*, **70**, 309-316.

Bardana, E.J. & Montanaro, A. (1991) Formaldehyde: An analysis of its respiratory, cutaneus and immunologic effects. *Ann. Allergy*, **66**, 441-452.

Endo, Y., Miyazaki, T., Hikita, Y., Azuma, M., Ikeda, H., Fukunaga, K. & Endo, G. (2001) Sampling methods and residential factors affecting formaldehyde concentration in indoor air. *Tohoku J. Exp. Med.*, **195**, 227-236.

Environmental Protection Agency (EPA) (2001) http://www.hsh.com/pamphlets/hazards.html. (2/9/2001) Environmental Hazards in the Home.

International Agency for on Cancer (IARC) (2004) Summary of Data Reported and Evaluation, http://www.iarc.fr/, Chem. Abstr. Name: Formaldehyde. (20.10.2004) CAS No: 50-00-0 **88**

Krzyzanowski, M., Quackenboss, J.J. & Lebowitz, M.D. (1990) Chronic respiratory effects of indoor formaldehyde exposure. *Environ. Res.*, **52**, 117-125.

La Dau, J. (1997) *Occupational and Environmental Medicine*, 2nd ed., Lange, 246.

Liebling, T., Rosenman, K.D., Pastides, H., Griffith, R.G. & Lemeshow, S. (1984) Cancer mortality among workers exposed to formaldehyde. *Am. J. Ind. Med.*, **5**, 423-428.

Norback, D., Bjornsson, E., Janson, C., Widstrom, J. & Boman, G. (1995) Asthmatic symptoms and volatile organic compounds, formaldehyde and carbon dioxide in dwellings. *Occup. Environ Med.,* **52**, 388-395.

Occupational Safety and Health Administration (OSHA) (2004) http://www.osha.gov/SLTC/woodproducts/index.html, 15.06.2004.

Operation Manual (2000) PPM Formaldemeter 400. Formaldehyde Monitor, PPM Technology Limited, Bangor, Gwynedd, LL57 4BL, United Kingdom.

Rumchev, K.B., Spickett, J.T., Bulsara, M.K., Phillips, M.R. & Stick, S.M. (2002) Domestic exposure to formaldehyde significantly increases the risk of asthma in young children. *Eur. Respir. J.,* **20**, 403-408.

SPSS Base User's Guide 11.0, SPSS Inc., Chicago, 2001.

States of California Air Resources Board-Research Division (2001) Guidelines: Indoor Air Quality-Formaldehyde in the Home, http://www.arb.ca.gov/research/indoor/formald.htm

Swenberg, J.A., Kerns, W.D., Pavkov, K.L., Mitchell, R.I. & Gralla, E.J. (1980) *Mechanisms of Toxicity and Hazard Evaluation*. Amsterdam, 283-286.

Wallace, B.R. (1998) Maxcy-Rosenau-Last. In: *Public Health and Preventive Medicine*, 14th ed., Appleton & Lange, Stamford Connecticut, Section 23, 531.

Wantke, F., Demmer, C.M., Tappler, P., Gotz, M. & Jarisch, R. (1996) Exposure to gaseous formaldehyde induces IgE-mediated sensitization to formaldehyde in school-children. *Clin. Exp. Allergy*, **26**, 276-280.

Yang, Z., Zhang, Y.P., Chen, D., Chen, W.G. & Wang, R. (2001) Eye irritation caused by formaldehyde as an indoor air pollution- a controlled human exposure experiment. *Biomed. Environ. Sci.,* **14**, 229-236.