

FORMALDEHYDE EXPOSURE AND ITS HEALTH HAZARDS IN A MELAMINE DINNERWARE MANUFACTURING INDUSTRY

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ABSTRACT

This paper reports on formaldehyde exposure and its health hazards in a melamine manufacturing industry. The mean of workers' exposure was measured according to 3500 NIOSH and was found to be 1.44 ± 0.21 , and 2.17 ± 0.24 ppm in morning and evening shifts, respectively. For stationary ones it was 1.37 ± 0.20 , and 2.06 ± 0.25 ppm, respectively. The results show that formaldehyde concentration at the sources (presses) depends on the weight of the resin used, and differences in concentration of various quantities of the applied resin with one another was significant ($p < 0.05$).

Based on the results of 272 samples, it was noted that formaldehyde concentration in the evening shift was more than that of the morning shift ($p < 0.05$), and from 3-6 P.M. is at maximum levels, except the polish workshop was less than 10 mg/m^3 (TLV-PNOC). In pressing workshops, all particles were respirable, whereas in the polish workshop, respirable particles comprised only 24% of all particles.

Exposure to formaldehyde was associated with several symptoms including eye burning, lacrimation, excessive blinking, nose and throat irritation and thirst, which were significantly higher in concentrations over 1 ppm compared with lower concentrations ($p < 0.05$).

Keywords: Formaldehyde, Resin, Exposure, Health.
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INTRODUCTION

Formaldehyde (HCHO) is one of the chemicals which has been the subject of much research in different countries. A fairly large number of workers are exposed to this substance in workshops. It has been estimated that 8000 workers were directly involved in the production of formaldehyde in the United States in 1976 and that a total of 1.4-1.75 million

workers were exposed to formaldehyde in 1979.^{9,10} One of the special applications of formaldehyde is its use in melamine dinnerware, wood and particle-board industries, and preparation of various glues and resins.^{4,10} The results of measurement of this substance in plastic industries shows that formaldehyde mean concentration in personal samples is 2.4 mg/m^3 and in stationary ones is 0.24 mg/m^3 ,⁸ and the above findings in the particle-board industry is 1.25-6.13

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mg/m³ and in hospitals which use this substance for sterilization and for preserving tissues, the concentration of formaldehyde in air measured over 2000 µg/m³.⁹

Formaldehyde principally causes irritation of the eyes and mucous membranes of the upper respiratory tract,⁸⁻¹⁰ and introduction of this substance is thought to be carcinogenic in humans, especially for the upper respiratory system.^{1,3,7} These facts emphasize the importance of research in this field.

The present research was conducted for the first time in Iran in order to evaluate the level of workers' exposure to formaldehyde in a melamine dinnerware industry, as well as the study of its effects on workers' health.

MATERIALS AND METHODS

This research has taken place in a melamine manufacturing factory which is one of the factories from the Tehran production complex. This factory is situated at kilometer 12 of Karaj Special Road. The scheme of the production process of this factory is shown in Fig. 1.

In this factory, 47 workers are employed: 28 are press operators, 8 molders and head of the shift, and 11 people work as bakers and polishers. The plant operates on a two 8-hour shift basis and the workers work in rotational shifts (one week in the morning, the next week in the evening).

Table I. Mean and standard deviation of formaldehyde concentration in presses in terms of their characteristics.

Characteristics of Presses	Concentration of Formaldehyde in Sources (ppm)		
	N	\bar{X}	S
Molding Temperature (°C)			
210-215	3	28.56	12.74
215-230	6	47.91	14.05
230-245	8	73.31	35.28
Molding Time (Sec)			
80-95	4	39.53	9.78
95-110	9	52.33	28.39
110-125	4	82.66	37.80
Weight of Resin (g)			
210-310	5	33.24	13.10
310-410	7	47.24	12.62
410-510	5	92.57	30.05
Area			
1	10	49.24	27.25
2	7	53.72	32.40

In pressing workshops, there was a total of 23 presses (16 one-storey and 7 two-storey presses). However, at the time of this research, 17 presses have been operating and all were working as a one-storey apparatus.

After the required pre-tests for determining the time and duration of air sampling and factors such as the procedure of

Table II. Mean and standard deviation of formaldehyde concentration in the morning shift.

Type of sampling	Statistical indices	Molding time (sec)			Molding temperature (°C) ^o			Weight of resin (g)			Area	
		80-95	95-110	110-125	200-215	215-230	230-245	210-310	310-410	410-510	1	2
Personal	\bar{X}	1.35	1.41	1.59	1.32	1.43	1.48	1.36	1.42	1.54	1.35	1.56
	S	0.12	0.14	0.35	0.09	0.20	0.25	0.12	0.17	0.31	0.11	0.26
	N	4	9	4	3	6	8	5	7	5	10	7
Stationary	\bar{X}	1.26	1.33	1.56	1.31	1.38	1.38	1.31	1.35	1.45	1.28	1.50
	S	0.10	0.15	0.28	0.04	0.19	0.25	0.12	0.16	0.31	0.10	0.24
	N	4	9	4	3	6	8	5	7	5	10	7

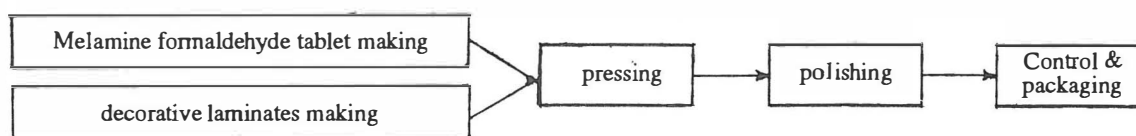


Fig. 1. The scheme of the production process of a melamine dinnerware manufacturing factory.

the press installation [by which the workshop was divided into two areas, I and II, Fig. 2], molding time, molding temperature, weight of the resin consumed and other parameters, the research was carried out in several stages as follows:

1. Determination of the formaldehyde concentration in contaminant sources (presses) using formaldehyde detector tubes and pumps (Gastec Company).

2. Determination of the workers' exposure to formaldehyde at different periods of time, i.e., in the morning and evening, and calculation of average formaldehyde concentration in different shifts. For air sampling, bubblers with sodium bisulfite absorbent were used and sample analysis took place by using chromotropic acid indication through a colorimetric method according to 3500 NIOSH method.⁵ A total of 272 air samples were collected and analyzed.

3. Determination of total and respirable particle concentrations through gravimetric method, by using cyclone, close face filter cassette, membrane filter with 0.8 pore size and diameter of 25 mm.

4. Investigation of the effects of formaldehyde on workers' health through completing appropriate questionnaires by interview and analysis.

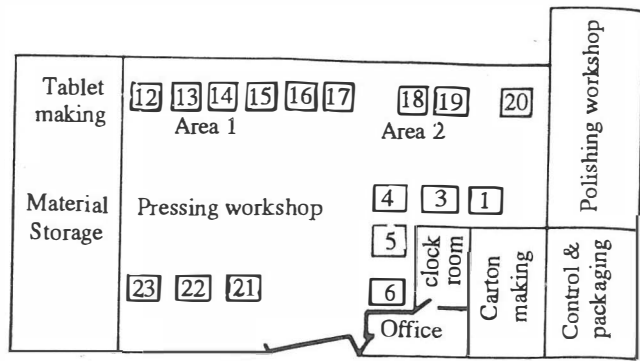


Fig. 2. Layout of melamine dinnerware plant.

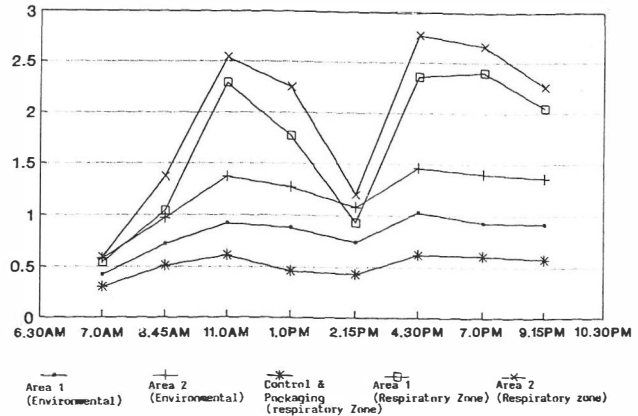


Fig. 3. Mean concentration of formaldehyde at different hours.

RESULTS

The results of formaldehyde concentration in contaminant sources (presses) at the end of the first stage of molding, i.e., the time predicted to have the highest level of formaldehyde gas emission, are shown in Table I in terms of molding conditions and dividing the press areas. Analysis of variance of mean concentration of formaldehyde in contaminant

sources in terms of press temperatures and molding times was not significant, but in relation to the consumed resin weight, the obtained difference was statistically significant ($p < 0.05$), whereas on the basis of t-test, the mean concentration of formaldehyde in areas 1 and 2 did not reveal any significant difference.

Table III. Mean and standard deviation of formaldehyde concentration in the evening shift.

Type of sampling	Statistical indices	Molding time (sec)			Molding temperature (°C)			Weight of resin (g)			Area	
		80-95	95-110	110-125	200-215	215-230	230-245	210-310	310-410	410-510	1	2
Personal	\bar{X}	2.09	2.14	2.33	1.99	2.19	2.23	2.10	2.19	2.22	2.09	2.29
	S	0.10	0.21	0.37	0.11	0.22	0.28	0.17	0.20	0.36	0.17	0.29
	N	4	9	4	3	6	8	5	7	5	10	7
Stationary	\bar{X}	1.96	2.02	2.25	1.92	2.06	2.11	1.98	2.08	2.10	1.95	2.21
	S	0.15	0.20	0.38	0.10	0.23	0.30	0.18	0.18	0.40	0.18	0.28
	N	4	9	4	3	6	8	5	7	5	10	7

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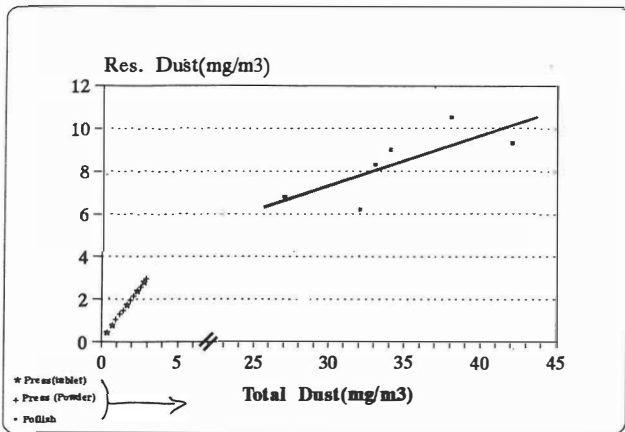


Fig. 4. Proportion of respirable particles to total dust.

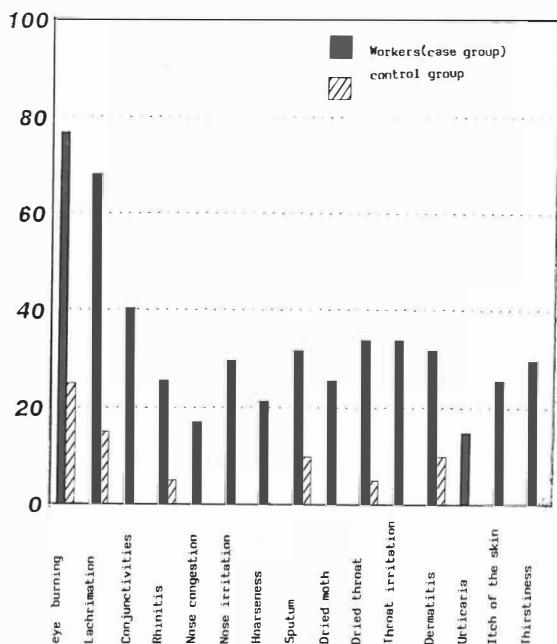


Fig. 5. Prevalence of eye, respiratory system and skin irritation resulting from formaldehyde exposure in workers and control group.

The results of workers' exposure to formaldehyde in two sample positions (personal and fixed installation at breathing zone height) and for the two shifts (morning and evening) are presented in Tables II and III. The results suggest that all workers are exposed to concentrations over 0.3 ppm. (ACGIH, 1994-95),¹ and also formaldehyde concentration in personal samples is more than that of fixed samples installed at breathing height ($p < 0.05$). The mean concentration of formaldehyde in the evening shift showed a considerable difference from that of the morning shift ($p < 0.05$). Based on 48 air samples collected and analyzed as stationary samples and the results reflected in Fig. 3, it was

Table IV. Mean and standard deviation of respirable and total dust concentration in different workshops.

Workshop	Respirable dust			Total dust		
	N	\bar{X}	S	N	\bar{X}	S
Press						
-Use of tablet	6	0.56	0.10	6	0.56	0.10
-Use of powder	18	1.98	0.45	18	1.98	0.45
Polish	6	8.35	1.59	6	34.33	4.77

noted that the highest level of formaldehyde concentration occurs at 3-6 P.M. (2.81 ± 0.40 ppm).

In the melamine manufacturing factory, in addition to formaldehyde gas, air pollution by particles is one of the prevalent problems due to the use of melamine formaldehyde tablets and powder. Hence, a total of 30 samples were taken in workers' breathing zones, of which 18 samples were collected near the presses during the use of melamine formaldehyde powder, 6 when melamine-formaldehyde tablets were being used, and 6 samples from polishers' breathing zones. The data is presented in Table IV. Fig. 4 shows the proportion of respirable particles to all particles in different work shops.

The effect of formaldehyde on the worker's health was evaluated by completing and analyzing a questionnaire. The prevalence of eye, respiratory system and skin irritation resulting from formaldehyde exposure in workers and control group ($n = 20$) is given in Fig. 5.

DISCUSSION

Regarding the production process, presses are the main source of release and emission of formaldehyde gas. Our findings show that the concentration of this gas depends on the consumed resin weight and it should be noted that molding temperature and time can not be determinants of formaldehyde concentration, because these two factors have a mutual role and both factors themselves depend on the consumed resin weight. Our results are in total agreement with other studies.^{8,10}

The mean concentration of formaldehyde in the evening shift was greater and hence workers are more heavily exposed to this pollutant in the evening shift. One of the reasons is the higher background concentration of the workshop at the beginning of the evening shift (0.74 ± 0.002 ppm) compared with background concentration at the beginning of morning shifts, 0.5 ± 0.001 ppm). Most workers tend to work harder in evening shifts, so that from 3-6 P.M., all presses are active. Moreover, at the beginning of the morning shifts, the presses have just started and it takes some time for them to warm-up, thus formaldehyde concentration is relatively low in the first hours of morning shifts. One reason for the presence of rotational shifts is the relatively obvious difference in formaldehyde concentrations

in morning and evening shifts.

However, the difference in personal and fixed samples' concentration in the workers' breathing zone has been significant only in area 1 while there is not such a difference in area 2. According to this result, one can say that since 7 presses are placed close together in a small space of the workshop in area 2, while in area 1, 10 presses are installed at large intervals in a relatively greater space, therefore the background concentration in area 2 is higher than that of area 1. On the other hand, all fans of the workshops are of the vacuum type and the major part of the replacement air is supplied through the major entrance door of the press workshop, and this issue has an important role in air stream direction, so that the air flow is from area 1 toward area 2. This issue causes the background concentration of formaldehyde to increase in area 2, thus the results from personal samples and fixed, installed samples in breathing zones of area 2 do not show any statistically significant differences.

Concerning air pollution by particles, despite the fact that the total concentration of particles in the press workshop is less than 10 mg/m^3 and in the polishing workshop, it is significantly more than 10 mg/m^3 , one should consider that the particles in the press workshop were smaller, so that all particles are respirable. However, in the polish workshop, respirable particles comprise 24% of the total particles. Paying attention to this issue has an essential role in designing the control system in these two workshops.

Regarding workers' health and their complaints, it is concluded that our findings are in accordance with results from the studies of Hedenstiverma,² and Olsen,⁶ so that eye burning, lacrimation, conjunctivitis, rhinitis, nasal congestion, nasal irritation, dry mouth, throat irritation, hoarseness, urticaria, itching, and thirst are key signs and symptoms that can be of importance in the investigation of the effect of formaldehyde on individual health, though eye burning, lacrimation, excessive eye blinking, nose and throat dryness and thirst are considerably greater in

concentrations over 1 ppm than at lower concentrations ($p < 0.05$).

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