

Original Paper

# Relationship between the Ambient Concentration of Mixed Solvents in Workplaces and the Concentration of Solvents in the Breathing Zone of Workers

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## Abstract

To investigate the relationship between stationary monitoring and personal monitoring in workplaces using solvent mixture, three sets of air samples were taken. A first set of samples (WP) was taken at many points equally distributed in the workplace to get an average value. This result will hereafter be requested to as A sampling. A second set (NW) was obtained from places near the position of the workers and a third set (BZ) was secured from the breathing zone of the workers. Close correlations were found among the concentrations for each air sampling, i. e., there was a close relationship when comparing (NW) to (BZ) and (WP) to (BZ).

The concentration of solvents in the breathing zone of workers was found to be higher than the geometric mean of ambient concentrations by the A sampling method and lower than the concentrations at the places at which workers exposure was considered to be at a maximum, the B sampling method.

The results suggest that the concentration of solvents in the breathing zone of workers is approximately equal to the concentration of solvent vapors taken near the positions of workers by the A sampling method, and thus the latter is a useful indicator of the amount of exposure to workers who remain in the same place for most of the work day.

## Introduction:

Control of the ambient concentration of mixed solvents has been the first step in

protecting workers against the adverse effects of solvents.

Ambient monitoring may involve monitoring at the work station (stationary monitor-

ing) and personal monitoring, depending on the sampling systems<sup>1)</sup>. In Japan, stationary monitoring has been conducted according to the requirements of the Working Environment Measurement Law since 1975<sup>2)</sup>. However, personal monitoring is not included in the regulations. Instead, biological monitoring of eight kinds for solvents has been carried out since 1989<sup>3)</sup>. In a previous paper<sup>4)</sup>, we described the relationship among stationary monitoring, personal monitoring and biological monitoring in a workshop using toluene.

In the present investigation, the detailed relationships between stationary monitoring and personal monitoring in workplaces using mixed solvents were investigated quantitatively.

## Materials and Methods

### *Test solutions:*

All reagents used were reagent grade.

### *Sampling points for vapors of solvent mixtures:*

Generally, control levels have been established by a combination of the results of A and B samplings according to the Working Environment Measurement Law<sup>1)</sup> from the Ministry of Labour.

### *Sampling method for vapor mixtures in the workplaces:*

Solvents in the ambient air were absorbed by activated charcoal in a passive sampling tube (Shibata Chemical Co, Tokyo), desorbed with 2-hydroxypyridine (Wako Pure Chemical Industries, Osaka) and applied to a gas chromatograph<sup>5)</sup>.

### *Sampling method for vapor mixtures in the breathing zone of workers:*

The glass tubes used for the sampling for personal exposure to solvent vapors had two layers of charcoal with a layer of glass wool between them. One end of the tube was open and the charcoal, weighed 100mg, was put in

the tube from the open side. 2-Hydroxypyridine was used for the desorption of solvents from charcoal as described above.

### *Headspace-gas chromatograph:*

Concentrations of solvent gases desorbed with 2-hydroxypyridine were determined by head space-gas chromatography. The analytical procedure was described in a previous report<sup>5)</sup>.

### *Calculation of the Hazardous Index:*

The hazardous index (K) for mixed solvents is calculated using the following equation as described by the ACGIH<sup>6)</sup>.

Where  $C_i$  = airborne concentration of solvents  $i$ ,  $T_i$  = the threshold limit value of solvents  $i$  and  $n$  = number of solvents in solvent mixture.

## Results

### *Relationship between the vapor concentrations of mixed solvents in the breathing zone of workers and concentrations in the proximity of workers:*

Kinds of work, kinds of solvents used and the numbers of workers in seven workplaces are shown in Table 1. The vapor concentrations of mixed solvents in the breathing zone of workers, the ambient concentrations in the workplaces by A and B sampling methods and concentrations in the air in the proximity of work stations are shown in Table 2. Vapor concentrations of solvent mixtures are expressed as the hazard index considering the effect of the mixed solvents on workers.

The mean concentration of solvents in the breathing zone of workers was  $0.48 \pm 0.50$  ( $m \pm SD$ ) and that of the air in the proximity of the work station was  $0.37 \pm 0.35$ . There was a significant close correlation ( $p < 0.05$ ) with a correlation coefficient of 0.89 between these two concentrations. A significant close

**Table 1** Type of industry, kinds of work performed, kinds of solvents used and number of workers in workshops

No. of Types of Industry	Kinds of Work	Solvents Used	No. of Workers
1. production of video tape	mixing paint	MEK, toluene cyclohexane	2
2. production of video tape	mixing paint	MEK, toluene cyclohexane	2
3. production of plywood	seasoning wood	styrene	4
4. production of plywood	apply styrene on board & hot press	styrene	10
5. production of speaker	bonding cone & dumper	MEK, toluene, n-hexane dichloromethane acetone	30
6. production of speaker	bonding gasket & dumper	MEK, toluene, n-hexane dichloromethane acetone	50
7. production of metal parts	rinsing of iron	trichloroethylene	3

MEK = methylethyl ketone

correlation ( $p < 0.05$ ) was also obtained between vapor concentrations of mixed solvents in the breathing zone of workers and ambient concentrations by A and B sampling.

In workshop No.1, personal samplings were taken at a time when workers were being exposed to the extremely high concentrations of solvents in a limited period of working time. Sampling was taken in the breathing zone of workers and in the proximity of the work station during a period of mixing paint with solvents. Therefore breathing zone values were relatively high, resulting in a low N/P (ambient concentrations in the proximity of the workers /air concentration in the breathing zone) ratio of 0.54.

If the workshop No.1 is omitted, the mean concentration in the breathing zone was

$0.31 \pm 0.32$  ( $m \pm SD$ ) and the concentrations in the proximity of the workers was  $0.30 \pm 0.34$ . These values approximately the same. The regression equation between them was  $y = -0.02 + 1.06x$  with a correlation coefficient of 1.0. In the regression equation, x is the concentration of breathing zone of workers and y is the ambient concentration in the proximity of workers. The above equation indicates that when vapor concentration in the proximity of the workers by A sampling method (y) and worker concentrations of vapors in the breathing zone (x) are almost identical.

*The relationship between concentrations of vapors on the breathing zone of workers and concentrations by B sampling :*

In the workshop No.1, workers were locat-

ed at a place near the tanks, paints were mixed with solvents and thus were exposed to higher concentrations of solvent vapors. Under these conditions, the concentrations by B sampling (B) were similar to concentration in the breathing zone of workers (P). The B/P value of 1.35 was the lowest found in any workshops and was the closest to 1.0 among all B/P values.

In workshop No.2, the workers weighed paints and then dissolved the paints with solvents in a tank. The B/P ratio (2.06) was higher than the ratio from workshop No.1.

In workshop No.3, two workers were situated at the entrance of the drying oven where higher concentrations of solvents were observed but the other two workers were situated

at the exit of the drying oven where extremely low concentrations of solvents were found. These working conditions resulted in a higher B/P ratio than the ratio from workplace No.2 because the average concentration in the breathing zone of workers was relatively low.

In workshop No.4, ambient concentrations changed with time and a higher B/P ratio was obtained because the concentrations by B sampling were high at various time and places in the workshop and P was calculated as the average concentration in the breathing zone during workers in the work period.

In workshop No.5 and No.6, there were no source generating higher concentrations of solvents. This resulted in a lower B value and a lower B/P ratio. In addition to this, the A

**Table 2** Relationship between ambient concentrations in the workshop and concentrations in the breathing zone of workers.

No WP	No WS	Per. Exp.	Near	Sampling		A-B Am	A-B Gm	N/P	A/P	B/P	Am/P	Gm/P	B/A
I	1	1.32	0.71	0.49	1.81	1.15	0.94	0.54	0.37	1.37	0.87	0.71	3.69
	2	0.88	0.91	0.20	1.81	1.01	0.60	1.03	0.23	2.06	1.14	0.66	9.05
	3	0.25	0.26	0.15	1.10	0.63	0.41	1.04	0.60	4.40	2.50	1.64	7.33
	4	0.15	0.13	0.08	0.80	0.44	0.25	0.87	0.53	5.33	2.93	1.67	10.00
	5	0.15	0.10	0.08	0.26	0.17	0.14	0.71	0.57	1.86	1.21	1.00	3.25
	6	0.11	0.12	0.11	0.21	0.16	0.15	1.09	1.00	1.91	1.45	1.36	1.91
	m	0.48	0.37	0.19	1.00	0.59	0.42	0.88	0.55	2.82	1.69	1.18	5.87
	SD	0.50	0.35	0.16	0.71	0.42	0.31	0.22	0.26	1.63	0.83	0.44	3.36
	r	1.00	0.89	0.93	0.88	0.93	0.97	-0.51	-0.69	-0.50	-0.60	-0.77	0.01
	p	—	*	**	*	**	**	—	—	—	—	—	—
	IC	0.00	0.07	0.05	0.40	0.23	0.13	0.98	0.72	3.58	2.15	1.50	5.84
	SL	1.00	0.62	0.29	1.24	0.77	0.60	-0.22	-0.36	-1.60	-0.98	-0.68	0.08
II	1	0.26	0.39	0.33	3.00	1.67	0.99	1.50	1.27	11.5	6.42	3.81	9.09

I = Workers in the workshop throughout working time, II = Workers in the workshop at working time only when needed. No WP = Number of workplaces, No WS = Number of workshop, Near = Data sampled near workplace in the stations by A sampling. A-B Am = Arithmetic mean of data from geometric mean by A sampling and B sampling. A-B Gm = geometric mean of data by A and B sampling. P = concentration of personal exposure, A = data from geometric mean by A sampling. B = data by B sampling, Am = arithmetic mean, Gm = geometric mean. m = mean, SD = standard deviation, r = correlation coefficient between Per. Exp. and solvent concentrations from other data. \* < 0.05, \*\* < 0.01 IC = intercept of regression line  $\alpha$ , SL = slope of regression line,  $\beta$  ( $y = \alpha + \beta x$ ,  $x$  = conc. of personal exposure). Values are expressed as hazardous index (K). In near, when No 1 is omitted, then Per. Exp.; m = 0.31, SD = 0.32, Near; m = 0.30, SD = 0.34, When Data of No.1 was omitted the values of r = 1.00, IC = -0.02, SL = 1.06 were calculated.

(A sampling)/P (personal exposure) ratio was 1.0 in workshop No.5, because the workers were distributed uniformly in the workplace and there were no distinct sources generating solvent vapors.

In workshop No.7, workers entered rooms only when necessary. This resulted in extremely high B (B sampling)/P value of 6.42 and high N (near position of workers)/P value because of the lower P value. In this kind of case, a time study of exposure to workers or direct measurements by personal exposure samplers attached to workers are necessary.

*Relationship between solvent concentration of breathing zone of workers and mean values of concentration by A and B sampling:*

The results are also shown in Table 2.

In general, the concentration in the breathing zone was higher than those by A sampling and lower than ambient concentrations by B sampling ( $A < \text{breathing zone} < B$ ).

The concentration in the breathing zone was similar to both the geometric mean and arithmetic mean of ambient concentrations by the A sampling and B sampling methods.

These results indicate that the relationship between vapor concentration of solvents in the breathing zone and ambient concentrations in workplaces by A or B sampling depends on the distribution of workers in the work room and the presence or absence of sources generating solvent vapors. Also the vapor concentrations of solvents found in the proximity of the workers were similar to concentrations of solvents found in the breathing zone. In practice, it should be possible to use particular results from the A sampling method, i. e., those samples taken in the proximity of the workers.

#### Discussion:

The results of the present experiment con-

firmed a previous report<sup>4)</sup>. Statistical methods were used to quantify the relationship among the vapor concentrations of mixed solvents in the breathing zones of workers, the concentrations in the workplaces and the concentrations in the proximity of the workers.

In Japan, control levels of airborne concentrations of solvents are established by A and B sampling as requested by the Working Environment Measurement Law<sup>2)</sup>. A sampling determines the average concentration of chemicals in the air of unit workplaces. B sampling measures the concentration at a particular place and time when the worker's exposure is considered to be at a maximum.

The concentration of solvents in the breathing zone was compared to the concentration obtained by A and B sampling. The data indicated that when workers are located in positions in the workplaces where solvent concentrations in the air are at an average level, the concentration of solvent in the breathing zone is similar to concentrations by A sampling rather than those by B sampling. The data also showed that when workers are engaged in washing or mixing work using solvents and thus are located in positions where higher concentrations of solvents are found, the concentration of solvents in the breathing zone is similar to concentrations by B sampling rather than those by A sampling under these conditions.

The concentration of solvents in the breathing zone of workers is higher than those by A sampling and lower than those by B sampling and is similar to the arithmetic and/or geometric mean.

In the present study: ① A sampling was done at not less than five proper sampling points in accordance with the regulations of the Ministry of Labour. Sampling positions were located about 1.5 meter from the floor.

② Samplings of solvent vapors in the air were taken near the breathing zone of the workers. The sampling points were selected from A sampling points near the workers position out of the positions. ③ The sampling points for B sampling are also described in the Working Environment Measurement Law. The law requires that samples be taken at points at which and at a time when the manufacturing process and working conditions indicate that the workers are being subjected to the greatest exposure. Sampling methods used were described in a previous report<sup>4)</sup>.

The results of the present study also showed that when workers mostly remained in a fixed workplace and concentrations of solvents were relatively stable during their working time, the solvent concentrations in the proximity of the workers, were similar to those in the breathing zones of the workers. The results indicated that the former is a good indicator for the latter.

Therefore, a close correlation was found between the concentrations of solvent vapors in the breathing zone of workers and those near the working positions of workers. The

present report suggests that the concentrations of solvent vapors in the air in the proximity of workers, as selected from the A sampling method, are useful indicators of the concentrations of solvents in the breathing zones of workers.

An exception is the case where workers enter a room having extremely high concentrations of solvents only when entering is requested by the working process, as was the case in the workshop No-6. In such a case, workers should use a personal sampler or should receive biological monitoring.

In most workplaces in Japan, data on the concentrations of solvents in the breathing zones are not available because such measurements were not required by the Working Environment Measurement Law. Therefore, urinary biological monitoring should be implemented to measure the amount of exposure to workers.

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