Bull. Environ. Contam. Toxicol. (1984) 32:200–204

Bulletin of Environmental Contamination and Toxicology

An Exposure System for Organic Solvent Vapor

Miho Kumai,[1] Akio Koizumi,[1] Kazuo Morita,[2] and Masayuki Ikeda[1,3]

[1]Department of Environmental Health, Tohoku University School of Medicine, Seiryo-cho 2, Sendai, 980 Japan, and [2]Kimoto Electric Co., Funabashi-cho 2, Tennoji-ku, Osaka, 543 Japan

A servomechanized system for the exposure of small laboratory animals to the vapor of organic solvents was previously described (Koizumi and Ikeda 1981); as a basic performance, the system was able to generate the organic solvent vapors at any constant concentrations in a range of 10 to 1000 ppm with a coefficient of variation (CV) of less than 10%. Succeedingly, efforts were made to improve the function of the system to be able to generate the vapor at the concentration of below 10 ppm and also over 1000 ppm so that the system can simulate the exposures of the inhabitants near the factory (Verbeck and Scheffers 1980) as well as the cases of thinner/glue sniffers (Knox and Nelson 1966; Suzuki et al. 1974). The achievements will be reported in the present communication.

MATERIALS AND METHODS

The basic system was as previously described (Koizumi and Ikeda 1981). In brief, the organic solvent vapor was generated by bubbling of air (the flow rate of which was adjusted with a 20∿1000 ml/min range Mass Flow Controller, Model FC-260, Taylan Corp., Torrance, Calif., U.S.A.), and diluted with fresh air flowing at a constant rate (100 L/min) before being led into a pyramidal 350 L exposure chamber (four chambers were built in parallel). The sample air from each chamber was taken into a computer-directed flow selecting device so that a portion (1 ml) of the sample from selected chamber was injected into a FID-GC (Hitachi Model 163). The peak area for the solvent was measured and the value was converted to the concentration in reference to that of the standard methane gas of a known concentration. The data were fed into a com-

---

[3] Correspondence/reprint requests to: Prof. M. Ikeda

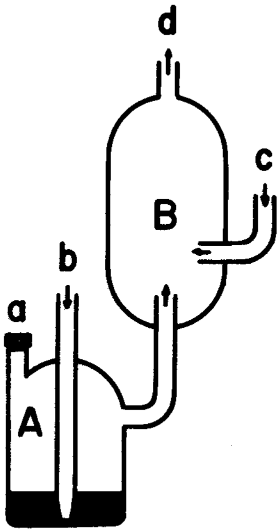

Fig. 1. A mini-bubbler with a mixing chamber.
A; a mini-bubbler with ca. 45 ml capacity.
B; a mixing chamber with ca. 48 ml capacity.
a; a diaphragm through which the liquid solvent will be supplied by injection.
b; the inflow of fresh air into the mini-bubbler.
c; the inflow of fresh air into the mixinig chamber for dilution.
d; the outflow of the vapor-impregnated air to the exposure chamber.

puter (Model DT 103, Kimoto Electric Co., Osaka, Japan) in order that the rate of flow to the bubbler could be adjusted to minimize the difference between the ordered and observed concentrations. One such loop took 6∿10 min depending on the retention time of the solvent(s) on the GC column; e.g., monitoring of the four chambers took ca. 25 min in case of toluene exposure.

For the generation and control of the vapor below 10 ppm, the following modifications were introduced: 1) A 1∿50 ml/min Mass Flow Controller was installed. 2) A mini-bubbler (ca. 45 ml in capacity) connected with a small mixing chamber (ca. 48 ml in capacity) (Fig. 1) was employed; the mixing chamber was to reduce fluctuation of concentration in the outflow, and the fresh air supply to the mixing chamber was at 500 ml/min. The bubbler - mixing chamber could be kept at 0°C when necessary. 3) The volume of the sample air was increased to 2 ml (or 4 ml when indicated) for better sensitivity in GC analysis. 4) Fresh air was passed through an activated carbon granule layer to remove hydrocarbon contaminant(s) before being supplied to the system. Air to the mini-bubbler and the mixing chamber was further treated with an oxidation catalyzer (Kimoto Electric Co., Osaka, Japan) prior to supply.

In order to generate the vapors at the concentrations of over 1000 ppm, several sets (as necessary) of a 500 ml bubbler connected with a constant flow air pump (1 or 2 L/min) were installed, from which the solvent vapor flow merged through Y-shaped tubes into

Table 1. Stability of vapor generation.

Solvent	Condition[a]	Ordered concentration[b]	Observed concentration			
			Mean[b]	SD[b]	CV[b]	N[b]
Toluene	I*	2	2.1	0.49	23.6	50
	I*,**	2	2.0	0.19	9.9	50
	I*	3	3.0	0.41	13.4	50
	I*,**	3	3.0	0.21	7.1	50
	I	4	4.0	0.24	6.0	50
	I	5	5.0	0.25	5.1	50
	I	7	7.0	0.30	4.2	50
	II*	10	10.0	0.72	7.2	50
	II	25	25.0	0.53	2.1	50
	II	45	45.0	0.75	1.7	50
	II	75	74.8	1.56	2.1	50
	II	100	99.9	1.27	1.3	50
	II	200	199.9	4.76	2.3	50
	II	300	301.7	6.82	2.3	50
	II	400	399.3	6.70	1.7	47
	II	500	501.4	8.19	1.6	50
	II	620	621.8	6.68	1.1	50
	III	1500	1451.5	61.03	4.2	50
	III	2500	2538.8	148.55	5.8	50
	III	3500	3505.4	126.15	3.6	50
n-Hexane	I*	5	5.0	0.23	4.5	50
	I*	5	5.0	0.22	4.4	143
	II*	45	45.1	1.42	3.1	50
	II*	45	44.9	1.42	3.2	143
	II	400	401.0	13.15	3.3	50
	II	400	399.8	11.83	3.0	143
	II	1000	996.7	36.81	4.5	50
	II	1000	998.3	31.58	3.2	156
	III	2500	2520.5	107.16	4.3	50
	III	2500	2483.9	101.76	4.1	143

[a] I; under the new conditions with a mini-bubbler and a low rate flow controller as described in MATERIALS AND METHODS.
II; under the conventional conditions as previously described (Koizumi and Ikeda 1981).
III; with additional bubbler(s).
*; the bubbler was kept at 0°C.
**; the air sample volume was 4ml in place of 2ml.

[b] Unit; ppm.

[c] Coefficient of variation (=SD/mean) in %.

[d] The number of determinations (one determination/ 25 min). N=47∿50 means an overnight run, while N=143∿156 indicates a 2.5 day (weekend) run.

the main computer-controlled flow to reach an exposure chamber.

RESULTS AND DISCUSSION

The performance of the system was tested under newly developed conditions designed to generate vapors below 10 ppm with a mini-bubbler and a low rate flow controller, and also those of over 1000 ppm with additional bubbler(s). The results are summarized in Table 1 in comparison with the performance in the 10∿1000 ppm range under the conventional conditions previously described (Koizumi and Ikeda 1981). Experiments were carried out with toluene and n-hexane.

Toluene at 10 ppm could be successfully generated under the conventional conditions with a 300 ml bubbler and a 20∿1000 ml/min flow controller when the bubbler was kept at 0°C to make toluene less volatile. Generation at lower concentration down to 2 ppm, however, could be achieved only under the new conditions described in MATERIALS AND METHODS. Even with the mini-bubbler coupled with the low rate flow controller, toluene was too volatile at the room temperature (20°C) to maintain the vapor at 2 ppm and the flow control below the lowest controllable limit was requested. The problem was solved by keeping the mini-bubbler at 0°C as shown in Table 1. The observed concentrations in terms of the means were essentially the same with the concentrations ordered in the below 10 ppm range under the new conditions or in the over 1000 ppm range with additional bubbler(s), as was in the 10∿1000 ppm range under the conventional conditions. Such agreement of the observed concentrations with the ordered concentrations was also established with n-hexane, although the higher volatility of n-hexane made it necessary to chill the bubbler at 0°C in order to maintain the vapor concentration at 5 ppm under the new conditions or at 45 ppm under the conventional conditions. It should also be noted that the CV tended to be larger as the lower concentration was ordered. The larger CV at the lower concentration was attributable, at least in part, to the limitation in the sensitivity of GC under the conditions employed, as the CV with toluene at 2 ppm was reduced from 23.6% to 9.9% when the volume of the air sample to be injected into the GC was augmented from 2 ml to 4 ml. Such improvement in CV with larger air sample volume was also observed when toluene at 3 ppm was ordered (Table 1).

The performance of the system was thus improved to cover a wider range of below 10 ppm to over 1000 ppm, and the system is currently applied in our laboratory to the experimental exposures of animals in organic solvent toxicity studies.

ACKNOWLEDGMENTS

This work was supported in part by a Grant-in-Aid for Scientific Research (No. 57870045 for 1982-3) to three of the authors (M.K., A.K. and M.I.) from the Ministry of Education, Science and Culture of the Government of Japan.

REFERENCES

Knox JW, Nelson JR (1966) Permanent encephalopathy from toluene inhalation. New Engl J Med 275:1494-1496

Koizumi A, Ikeda M (1981) A servomechanism for vapor concentration control in experimental exposure chambers. Am Ind Hyg Ass J 47:417-425

Suzuki T, Shimbo S, Nishitani H, Oga T, Imamura T, Ikeda M (1974) Muscular atrophy due to glue sniffing. Int Arch Arbeitsmed 33:115-123

Verbeck MM, Scheffers TML (1980) Tetrachloroethylene in exhaled air of residents near dry-cleaning shops. Environm Res 21:432-437

Received July 21, 1983: Accepted August 22, 1983