J. Science of Labour, Vol. 66, No. 1 (Part II) (10)～(15), 1990

ESTIMATION BY WEIGHT INCREASE OF THE SERVICE LIFE OF RESPIRATOR CARTRIDGES USED IN A PAINT MANUFACTURING PLANT

Shigeru TANAKA*, Shin-ichi ABUKU*, Keishichiro IMAIZUMI**, Tadao UTUNOMIYA**, Yukio SEKI* and Shun-ichiro IMAMIYA*

Key words: Paint manufacturing plant, Respirator cartridge, Breakthrough time, Organic solvent, Remaining filtration efficiency

I. Introduction

Organic vapour respirator cartridges are used for preventing workers' exposure to organic solvent vapour in workplaces dealing with various organic solvents. The estimation of the service life of the cartridges in the workplace, i. e., the time of the cartridge renewal, involve a few alternative methods. They include determination of the service life by comparing the breakthrough time as a function of carbon tetrachloride vapour in the newly-attained cartridges with the vapour concentration in the working environment[1], determination by means of identifying odour or irritation by organic solvents leaking from the cartridges[2], and determination by estimating an increase in the weight of cartridges in accordance with the adsorption of organic solvents[3]. However, few studies have been made on any of these methods while taking into consideration the real-life use of cartridges in the workplace.

Furthermore, whereas the breakthrough time of cartridges was investigated in detail by Nelson et al.[4-7], their study dealt only with single organic solvents. Thus, there have likewise been few reports on the effects of mixed solvents which are used widely in industries[8].

In the present study, we carried out a series of experiments so as to estimate the time of the cartridge renewal on the basis of the increase in weight of each cartridge being used in a paint manufacturing plant. First, a breakthrough test of cartridges was conducted for toluene vapour in order to determine the increase in weight of each cartridge at the breakthrough time. Secondly, the levels of exposure of workers to organic solvents in a paint manufacturing plant which mainly used toluene vapour were determined. The used cartridges were then collected from the workers, and the increase in weight of each cartridge was determined along with the determination of the amount of solvent entrapment as well as the determination using toluene vapour of the remaining filtration efficiency[9].

II. Methods

1. Breakthrough time of the cartridges for toluene vapour

The cartridges (Sanko Kagaku Kogyo Co., Ltd., Tokyo) filled with 22 grams of activated carbon were used in the present experiment. Figure 1 shows a test apparatus for measuring

* 田中茂, 安福慎一, 関幸雄, 今宮俊一郎
School of Hygienic Sciences, Kitasato University, 1-15-1, Kitasato, Sagamihara, Kanagawa 228, Japan
** 今泉敬七郎, 宇都宮忠生
Japan Industrial Safety and Health Association, Occupational Health Service Center, 5-35-1, Siba, Minato-ku, Tokyo 108, Japan

the breakthrough time of a cartridge. Fresh air coming out of the pump (No. 1 in the figure) was divide into two flows after passing through a drying tower (No. 3). One of the airflow branches was saturated with water vapour by bubbling the air through two impingers (No. 4). The humidity was controlled by the ratio of the flow rate of dry air to water-saturated air. Toluene vapour was supplied from two impingers, mixed with humidified air in a bulb and sent to the cartridge being tested (No. 9). The concentrations of toluene in the upstream and the downstream of a cartridge were determined by means of a gas chromatograph equipped a hydrogen flame ionization detector. The breakthrough time for different toluene vapour concentrations (100, 300, 500 and 1000 ppm) and the increase in weight of each cartridge at the breakthrough time were determined three times each under constant conditions, i. e., at a flow rate of 30 L/min, a temperature of 20 °C and a relative humidity of 50 %. The breakthrough time of a cartridge was defined as the time interval from onset of toluene vapour supplied into the cartridge until the time when the toluene concentration reached 5 ppm at the downstream of the cartridge.

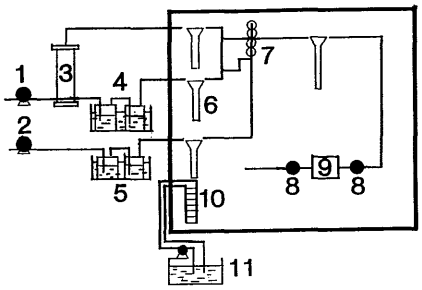

Fig. 1 A schematic diagram of the apparatus for measuring the breakthrough time of cartridges.
1, 2) pump, 3) dry tower, 4) humidifier, 5) toluene vapour generator, 6) flow meter, 7) mixer, 8) sampling point, 9) testing cartridge, 10) fan, 11) constant temperature bath

2. Investigations in a paint manufacturing plant

a. Determination of exposure concentrations for paint manufacturing workers

The workers at three sections of the paint manufacturing plant were individually examined. Passive samplers (Organic Vapor Monitor, 3 M Co., Ltd.) were attached to 38 workers throughout the working hours, and the exposure concentrations were determined over two days. Gas chromatograph analysis was performed after desorption by adding 1.5 ml of carbon disulfide.

b. Collection of the used cartridge

The workers were provided with organic vapour respirators on the days where the exposure concentrations were determined, and the weight of each cartridge was determined on each day. When the weight of the cartridge increased by 2 grams or more on the first day, the cartridge was collected, and a new cartridge was used on the second day. Thirty-two of 44 cartridges collected were subjected to the determination of the amount of organic solvents entrapped in the cartridges ; the activated carbon was collected from the cartridges, put in 1-L bottle and subjected to desorption in 300 ml of carbon disulfide, and the subsequent analysis was done by a gas chromatograph. The other 12 cartridges were subjected to a filtration test to entrap the residual toluene vapour for the toluene vapour concentration of 300 ppm at a flow rate of 30 L/min, at a humidity of 50 % and at a temperature of 20 °C by using the device shown in Fig. 1.

A gas chromatograph Type GC-8 A (Shimadzu ; hydrogen flame ionization detector) fitted with a packed column (5 % Benton 34 and 5 % DIDP on Uniport B) was applied for analysis.

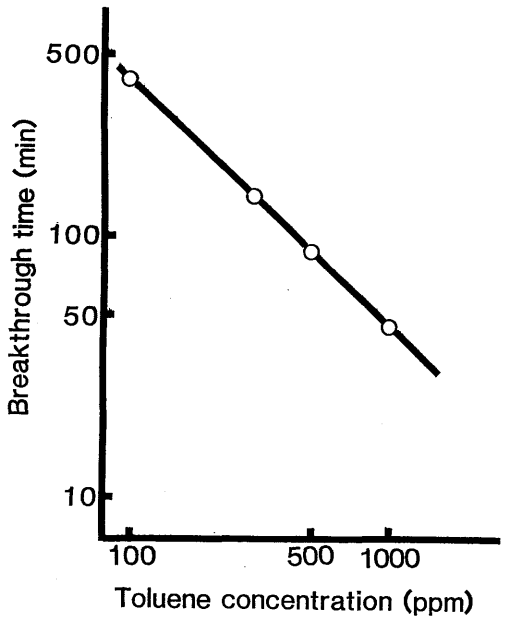

Fig. 2 Relationship between the toluene vapour concentration and the breakthrough time. Each circle represents a mean of the results for 3 cartridges. Airflow rate, temperature and relative humidity were fixed at 30 L/min, 20 °C and 50 %, respectively.

III. Results

Figure 2 shows the relationship between the toluene vapour concentration and the breakthrough time in the case of new cartridges. The relationship for a vapour concentration ranging from 100 ppm to 1000 ppm was represented by the following formula : log (breakthrough time in min)= −0.96 log (concentration in ppm)+4.52 (with the correlation coefficient of 0.999). The fact that the gradient in the formula was slightly less than −1.00 indicates that absorbed toluene was desorbed and diffused by long-time aeration as the toluene vapour concentration decreased. As a result, the increase in weight of cartridges at the breakthrough time was 6.4±0.3 g at 1000 ppm, 6.1±0.6 g at 500 ppm, 5.8±0.4 g at 300 ppm, and 5.0±0.4 g at 100 ppm, showing the tendency to decrease with a decrease in the concentration. Five grams was also considered as the standard increase in weight of each cartridge at the breakthrough time.

Table 1 shows the results concerning the exposure concentrations at each workplace section in the paint manufacturing process. The main components of the vapour were toluene and ethyl acetate at the first section, toluene, buthyl acetate and ethyl acetate at the second section, and toluene, xylene and ethylbenzene at the third section. The concentration at which workers were exposed to the organic vapour varied greatly between individual workers, while the increase in weight of a cartridge after work was within the range from 4.9 grams to 0.1 grams.

Figure 3 shows the relationship between the increase in weight of each cartridge and the

Table 1 Exposure concentrations for the paint manufacturing workers

Workplace sections	Number of persons	Organic solvents	Personal exposure (ppm)		
			Mean	Maximum	Minimum
1	10	Toluene	88	546	4
		Ethyl acetate	10	33	1
2	13	Toluene	49	188	2
		Buthyl acetate	55	628	1
		Ethyl acetate	36	121	2
3	15	Toluene	43	384	1
		Xylene	18	102	1
		Ethyl benzene	10	52	1

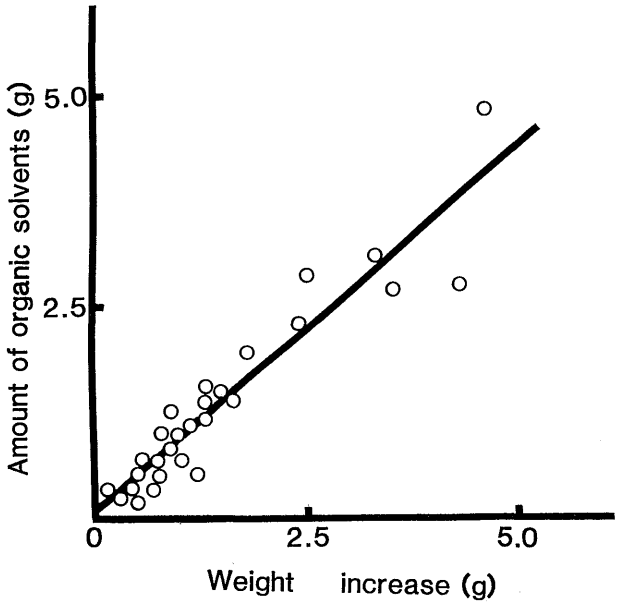

Fig. 3 Relationship between the weight increase in each cartridge and the amount of entrapped organic solvents.

amount of entrapped organic solvents. The relationship was significant, with the average ratio of the amount of entrapped organic solvents to the increase in weight of cartridges being 93.2 %. The remaining amount seemed to account for dust in the atmosphere and absorbed water vapour.

Figure 4 shows toluene vapour breakthrough curves for used cartridges. It was confirmed that a cartridge with an increase in weight less than the average showed a tendency toward entrapment of toluene. The concentration of transmitted toluene exceeded 5 ppm from the beginning of the experiment in cartridge No. 1 which had had a weight increase of 4.1 grams, presumably because the entrapped toluene vapour was diffused and transferred to the activated carbon. Figure 5 shows a relationship between the increase in weight of each cartridge and the remaining breakthrough time. There was an inverse correlation with a correlation coefficient of -0.873, between them.

IV. Discussion

There is a method in which the timing of the cartridge renewal is determined by identifying the corresponding point of the breakthrough curve of carbon tetrachloride vapour in new cartridges by knowing environmental concentrations of organic solvents. In the present study, however, it was impossible to determine such timing merely on the basis of the exposure concentration, because the organic solvents used were different from carbon tetrachloride and the concentration of organic solvents to which workers were exposed varied in the range of a two-digit number even within the same section of the plant.

A method for confirming the timing of cartridge renewal by means of odour of the organic solvents leaking from cartridges was discussed by Reist et al[10]. The results suggested that it was possible to rely on the olfactory sense only when the subject was exposed to a specific

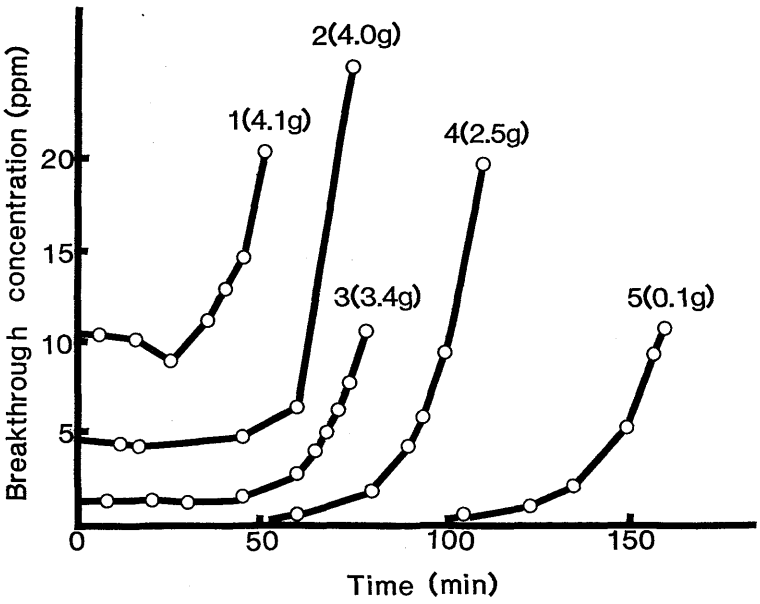

Fig. 4 Breakthrough curves for the toluene vapour in the case of used cartridges.
Toluene vapour concatration, airflow rate, temperature and relative humidity were fixed at 300 ppm, 30 L/min, 20 °C and 50 %, respectively. Weight in parentheses was the weight increase of the cartridge in the workplace.

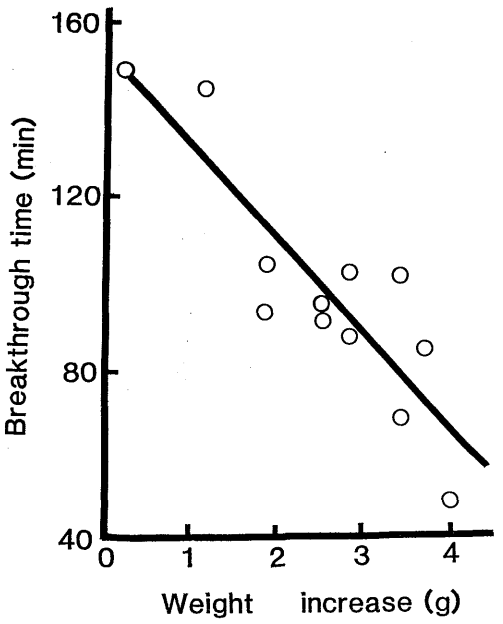

Fig. 5 Relationship between the weight increase in each cartridge and the remaining breakthrough time.

gas with a strong odour. As a result of the determination over one working day in an administration room where the workers worked without application of a respirator in the present study, the toluene concentration averaged 5.1 ppm (N=8, from 15 ppm to 0.1 ppm), which suggested that the sensitivity of workers to the odour of organic solvent gas would decrease with time. Thus, this method was also considered difficult to apply.

The increase in weight due to adsorption of organic solvents by the activated carbon filled in cartridges was examined in the present study. When the increase in weight of cartridges was in question, it was necessary to take into account the types of organic solvents used in the workplace and adsorbed water vapour. Coexisting organic solvents were toluene, ethyl acetate, butyl acetate, ethylbenzene and xylene in the present study. The results by Nelson et al.[4] showed a sli-

ghtly shorter breakthrough time of ethyl acetate and buthyl acetate than that for toluene, whereas few breakthrough was observed for solvents in the subsequent filtration test. The increase in weight of a cartridge due to adsorbed water vapour was attributed to the relative humidity in the place where it was used. The examination for two days revealed a range of relative humidity from 57 % to 30 % (temperature of 21 °C to 11 °C). Some reports have showed that adsorption of water vapour by activated carbon increases rapidly at a relative humidity of more than 50 %[6,11]. The mean ratio of entrapped organic solvent to the increase in weight of the cartridges was 93.2 % in the present study, which showes that the adsorbed water content was confirmed to be small.

As shown in Fig. 5, there was an inverse correlation between the increase in weight of the cartridge in the work places and the remaining filtration efficiency. This result suggested that the increase in weight of a cartridge at the time of cartridge renewal was about 4 grams. Kimura et al.[3] reported that the relation between the amount of entrapped organic solvents shown by a filtration test and the increase in weight of cartridges used in the case] of paint workers was characterized by an inverse correlation.

Consequently, it was demonstrated that the timing for renewal of a cartridge could be indicated by measuring an increase in the weight of each cartridge. In the general workplace, it seems necessary to consider the types of organic solvents used and adsorbed water.

References

1) Japanese Industrial Standard: Gas Masks JIS T 8152, Japanese Standard Association, 1981. (In Japanese)
2) National Institute for Occupational Safety and Health: A Guide to Industrial Respiratory Protection by J. A. Pritchard (DHEW/NIOSH, 76-189). 60, Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1976.
3) Kimura K., Ito A., Tanaka M. and Tanaka S.: A Study on the estimation of breakthrough in a respirator canister. *J. Sci. of Labour*, 65 (7), 391-402, 1989. (In Japanese)
4) Nelson G. O. and Harder C. A.: Respirator cartridge efficiency studies: V. Effect of solvent vapor. *Am. Ind. Hyg. Assoc. J.*, 35 : 391-399, 1974.
5) Nelson G. O., Harder C. A. and Bigler B. E.: Respirator cartridge efficiency studies: VI. Effect of concentration. *Am. Ind. Hyg. Ass. J.*, 37 : 205-216, 1976.
6) Nelson, G. O. and Harder C. A.: Respirator cartridge efficincy studies: VII. The Effect of relative humidity and temperature. *Am. Ind. Hyg. Assoc. J.*, 37, 280-288, 1976.
7) Nelson G. O. and Harder C. A.: Respirator cartridge efficincy studies: VIII. Summary and conclusions. *Am. Ind. Hyg. Assoc. J.*, 37 : 514-525, 1976.
8) Swearengen P. M. and Weaver S. C.: Respirator cartridge study using organic-vapor mixtures. *Am. Ind. Hyg. Assoc. J.*, 49 : 70-74, 1988.
9) Tanaka, S., Abuku, S., Imaizumi, K., Ishizuka, H., Seki, Y. and Imamiya S.: Efficiency of respirator canisters with methyl bromide. *Ind. Health*, 27 : 111-120, 1989.
10) Reist, P. C. and Rex, F.: Odor detection and respirator cartridge replacement. *Am. Ind. Hyg. Assoc. J.*, 38 : 563-566, 1977.
11) Hall, T., Breysse, P., Corn, M. and Jonas, L. A.: Effects of adsorbed water vapor on the adsorption rate constant and the kinetic adsorption capacity of the wheeler kinetic model. *Am. Ind. Hyg. Assoc. J.*, 49 : 461-465, 1988.

(Received: October 26, 1989)