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### Effect of sampling volume on the breakthrough of charcoal tube during vinyl chloride monomer sampling

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The main factors of breakthrough are known to sampling time, flow rate, concentration of the sample, temperature, humidity, and the physical characteristics of the solid sorbent tube. However, no study has been reported the effect of temperature and sampling volume on the breakthrough of a charcoal tube during vinyl chloride monomer (VCM) sampling. The objective of this study is to suggest the optimal sampling condition during VCM sampling based on National Institute for Occupational Safety and Health (NIOSH) method.

To evaluate adequate sampling volume for VCM without breakthrough, volume of 1, 2, 3, 4, and 5 L each from VCM of 1, 5, 10, 15, and 20ppm at flow rate of 0.05 L/min were sampled in 22 and 40 . At 22 , in the case of 1, 5, 10, and 15ppm, VCM was adsorbed completely in first section of charcoal tube regardless of sampling volume. But in 20ppm, detection rates are 99.56% in first section and 0.44% in second section. At 40 of 1ppm, VCM was adsorbed completely in first section. In 10, 15, and 20ppm, detection

rates of second, third, and fourth sections were decreased significantly by reduction of sampling volume. In determination of breakthrough based on NIOSH method, no breakthrough was occurred in 20ppm at 22 . At 40 , breakthrough was occurred in 10, 15, and 20ppm when sampling volume was 5L. Although no breakthrough was occurred when sampling volume was 3L.

Finally, in environment of temperature around 22 , breakthrough may not occurred up to 20ppm during sampling for VCM. During sampling for VCM in environment of temperature around 40 , no breakthrough occurred in 1-5ppm and 10-20ppm when sampling volume is 5L and 3L respectively. This result suggests that the sampling volume should be considered when VCM sampling under hot conditions (>22 ) by the NIOSH method No. 1007.

Key Words : Vinyl chloride monomer, Air sampling, Temperature, Sampling volume, Breakthrough

1. Polyvinyl chloride(PVC) VCM VCM (vinyl chloride monomer, PVC 1980 1 6 (angio- sarcoma of liver, scleroderma), (Doll, 1988). PVC (Allsopp Vianello, 1992), 1998 2 7 / (Kielhorn , 1999) 가

\* 2001 : 2001 9 20 , : 2001 12 22  
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1974; Veltman, 1975). 1977 PVC가 VCM (boiling 5L PVC point)가 -13.37 20 VCM PVC 1971 2,580mmHg VCM 가 VCM 가 500ppm 가 VCM 가 20% NIOSH (acroosteolysis) 가 50ppm (Susanne, 1987), VCM VCM (Baker Reiter, 1977; Gottesman, 1988). 1974 가 가 가 가 (Melcher, 1975). NIOSH 가 VCM 10%가 1974 VCM 1ppm (NIOSH, 1994). (Baker, 1977; Gottesman, 1988; OSHA, 1990). (American Conference of Governmental Industrial Hygienist, ACGIH, 2001) 가 1ppm Severs 1. VCM 1, 5, 10, 15, 20ppm 가 100 (232-50, SKC Inc., Eight Four, PA) (1998) Skoky(1975), Cuddeback (1975) VCM 가 VCM 가 (Fluka, Buchs, Switzerland) VCM 가 (NIOSH 6mm, 4mm, 70mm, 20/40mesh 100/50mg (226-01, SKC Inc., Eighty Four, PA) 2. 가 시료포집 방법 (Gil-air sampler 17GB, Gilian, Clearwater, Fla) 1, 5, 10, 15, 20ppm VCM 0.05 /min 20, 40, 60, 80, 100 VCM 1, 2, 3, 4, 5 가 1ppm (1998) ACGIH(2001) (National Institute for Occupational Safety and Health, NIOSH) No. 1007(NIOSH, 1994) (Occupational Safety and Health Administration, OSHA) Method No. 75(OSHA, 1984) VCM (sorbent sample tube) NIOSH 1007 5 10ppm (Control of Substance Hazardous to Health Regulation; COSHH, 1996) 7ppm coconut shell charcoal tube OSHA 75 carbon molecular sieve Skoky(1975) 0.21ppm 5ppm VCM 16ppm(0.4 ~ 40mg/m<sup>3</sup>) 16ppm 20ppm PVC 0.051ppm 206 ppm 5L 가 Severs 0.051ppm 200ppm VCM

가 27.6ppm (GC 5890 Series , 9.92 $\mu$ g, 9.34 $\mu$ g 5  
 (1994) Hewlett Packard, Wilmington, Del) 12.91 $\mu$ g, 12.98 $\mu$ g  
 (Ultra-2 capillary column) 100% ( 1).

NIOSH No.  
 1007 5 (0.05  
 /min 100 ) VCM  
 나. 5ppm에서의 공기 포집량에 따른  
 VCM의 검출 경향  
 가 - 22 1 , 2 , 3 , 4  
 NIOSH (5972, Hewlett Packard, , 5 VCM  
 2 Wilmington, Del) . 12.65 $\mu$ g, 24.98 $\mu$ g, 38.05 $\mu$ g, 50.73 $\mu$ g, 63.62  
 ( 1). First section second  $\mu$ g 100%  
 section Third section 3. 가  
 forth section 40  
 5 VCM , 5 98.95%,  
 , , 4 100%  
 Duncan 가  
 나. 시료 포집시 온도, 습도, 기압 (p<0.05), 1, 2, 3, 4  
 , 가 ( ) 100%  
 22 , 5  
 40 . 40 NIOSH 1.05%( 0.64 $\mu$ g)  
 (firth, second section) 10%가 가  
 (third, forth section) (p<0.05)( 2).  
 22 . VCM , (22 ,  
 (No. 740 40 ), 다. 10ppm에서의 공기 포집량에 따른  
 0-7440, Sato Keiryoki Co., Tokyo, Japan) VCM의 검출 경향  
 , 41 ~ 44% 6.12 SAS ver 22 1  
 1009.3 hpa .  
 24

다. 시료 분석 1. VCM  
 NIOSH No.  
 1007(NIOSH, 1994) .  
 , vial 가. 1ppm에서의 공기 포집량에 따른  
 (carbon disulfide, CS<sub>2</sub>) VCM의 검출 경향  
 1M $\ell$  22 40 1 VCM  
 . 3 가 2.58 $\mu$ g, 2.41 $\mu$ g 2  
 30 가 - 5.16 $\mu$ g, 4.64 $\mu$ g, 3 7.74 $\mu$ g, 7.22 $\mu$ g, 4

Table 1. Adsorbed amounts of vinyl chloride monomer by sampling volume and temperature in 1ppm

Temp.	Total volume ( )	Total amounts (μg)	Amounts of VCM (μg)			
			First section	Second section	Third section	Forth section
22	1	2.58±0.05 <sup>¶</sup> (100.00) <sup>‡</sup>	2.58±0.05 (100.00)	-	-	-
	2	5.16±0.14 (100.00)	5.16±0.14 (100.00)	-	-	-
	3	7.74±0.10 (100.00)	7.74±0.10 (100.00)	-	-	-
	4	9.92±0.86 (100.00)	9.92±0.86 (100.00)	-	-	-
	5	12.91±0.48 (100.00)	12.91±0.48 (100.00)	-	-	-
40	1	2.41±0.07 (100.00)	2.41±0.07 (100.00)	-	-	-
	2	4.64±0.25 (100.00)	4.64±0.25 (100.00)	-	-	-
	3	7.22±0.47 (100.00)	7.22±0.47 (100.00)	-	-	-
	4	9.34±0.73 (100.00)	9.34±0.73 (100.00)	-	-	-
	5	12.98±0.61 (100.00)	12.98±0.61 (100.00)	-	-	-

\*, p<0.05 by ANOVA; ‡, Distribution rates(%); ¶, Mean±S.D.; Temp., temperature; VCM, Vinyl chloride monomer

Table 2. Adsorbed amounts of vinyl chloride monomer by sampling volume and 6 temperature in 5ppm

Temp.	Total volume ( )	Total amounts (μg)	Amounts of VCM (μg)			
			First section	Second section	Third section	Forth section
22	1	12.65±0.47 <sup>¶</sup> 6				

22

(p<0.05), 1 2

VCM ( 3).

라. 15ppm에서의 공기 포집량에 따른 VCM의 검출 경향

22

100%( 38.66μg) 2  
( 76.383μg), 3 ( 116.18 μg), 4  
( 153.00μg), 5 ( 192.90μg)

100%가

40

5 4

63.02%, 3 80.27%, 2  
94.00%, 1 100%

가 (p<0.05).

5 4

15.71%, 2 5 19.27%, 3  
6.00%

(p<0.05) 1 VCM

5 4

4.02% 4 19.65%, 3

(p<0.05), 1 , 2

.

1.51%, 4 0.74%

(P<0.05) 1, 2, 3

VCM ( 4).

마. 20ppm에서의 공기 포집량에 따른 VCM의 검출 경향

22 , 1, 2,  
3, 4 100%가, 5

99.56%가

5 0.44%( 1.13μg)

가

4

1

가

40

Table 3. Adsorbed amounts of vinyl chloride monomer by sampling volume and temperature in 10ppm

Temp.	Total volume ( )	Total amounts (µg)	Amounts of VCM (µg)			
			First section	Second section	Third section	Forth section
22	1	25.82±1.73 <sup>¶</sup> (100.00) <sup>‡</sup>	25.82±1.73 (100.00)	-	-	-
	2	51.31±2.78 (100.00)	51.31±2.78 (100.00)	-	-	-
	3	77.66±2.64 (100.00)	77.66±2.64 (100.00)	-	-	-
	4	102.98±3.43 (100.00)	102.98±3.43 (100.00)	-	-	-
	5	129.20±3.24 (100.00)	129.20±3.24 (100.00)	-	-	-
40	1	25.50±0.96 (100.00)	25.50±0.96 (100.00)	-	-	-
	2	47.76±1.98 (100.00)	47.59±1.73 (99.66±0.75)	0.17±0.38 (0.34±0.75)	-	-
	3	76.77±4.53 (100.00)	67.76±3.39 (88.41±4.78)*	7.40±3.53 (9.52±4.21)*	1.60±0.50 (2.08±0.58)*	-
	4	96.68±4.08 (100.00)	76.03±5.63 (78.64±4.71)*	15.38±2.80 (15.91±2.79)*	5.26±1.85 (5.45±1.95)*	-
	5	120.81±2.29 (100.00)	78.78±6.71 (65.19±5.08)*	27.40±3.04 (22.69±2.56)*	14.63±3.10 (12.12±2.63)*	-

\*, p<0.05 by ANOVA; ‡, Distribution rates(%); ¶, Mean±S.D.; Temp., temperature; VCM, Vinyl chloride monomer

Table 4. Adsorbed amounts of vinyl chloride monomer by sampling volume and temperature in 15ppm

Temp.	Total volume ( )	Total amounts (µg)	Amounts of VCM (µg)			
			First section	Second section	Third section	Forth section
22	1	38.66±3.01 <sup>¶</sup> (100.00) <sup>‡</sup>	38.66±3.01 (100.00)	-	-	-
	2	76.38±1.51 (100.00)	76.38±1.51 (100.00)	-	-	-
	3	116.18±1.59 (100.00)	116.18±1.59 (100.00)	-	-	-
	4	153.00±2.15 (100.00)	153.00±2.15 (100.00)	-	-	-
	5	192.90±2.85 (100.00)	192.90±2.85 (100.00)	-	-	-
40	1	36.24±0.95 (100.00)	36.24±0.95 (100.00)*	-	-	-
	2	74.87±1.69 (100.00)	70.36±1.50 (94.00±2.33)*	4.51±1.82 (6.00±2.33)*	-	-
	3	106.95±2.76 (100.00)	85.92±6.36 (80.27±4.09)*	16.73±3.89 (15.71±3.95)*	4.30±0.18 (4.02±0.25)*	-
	4	146.65±2.77 (100.00)	92.40±5.01 (63.02±3.55)*	24.37±4.25 (16.59±2.71)	28.80±3.12 (19.65±2.24)*	1.08±1.51 (0.74±1.02)
	5	180.57±1.25 (100.00)	107.51±3.78 (59.53±1.72)	34.79±0.90 (19.27±0.54)*	35.55±1.10 (19.69±0.73)	2.72±1.35 (1.51±0.76)*

\*, p<0.05 by ANOVA; ‡, Distribution rates(%); ¶, Mean±S.D.; Temp., temperature; VCM, Vinyl chloride monomer

5 4  
4 59.80%, 3  
76.42%, 2 91.82%, 1 100%  
가 (p<0.05).  
5 3  
가 3  
15.66%, 2 7.89%, 1 0.00%  
가 (p<0.05),  
1 VCM  
5 4  
4  
22.35%, 3 7.92%, 2 0.28%, 1  
0.00%  
(p<0.05), 1  
5 1.94%,  
4 1.34%, 3 0.00%  
(p<0.05), 1, 2, 3  
VCM ( 5).  
2. VCM  
10%  
NIOSH(1994)  
(third section forth section)  
(first  
section second section)  
가 40  
1ppm 5ppm  
가 15ppm  
20ppm 3 4  
가가 4  
가 (1, 5,  
3  
10, 15, 20ppm) 가  
( 2).

4.73 95%  
 2.4591 ~ 9.0811 VCM  
 (ppm)가 1ppm 가 가  
 1.27 95%  
 1.1432 ~ 1.4117  
 ( 6). 22  
 가  
 , 40 가

VCM 가  
 . Saalwaechter  
 (1977) , ,  
 , ,  
 , 22 40

### 3. VCM

VCM NIOSH  
 (1994)  
 1 가 가 ,

40 1 4ppm Roh (2000) VCM 5  
100% 0 ~ 20ppm VCM 1  
5 2 22 20ppm 5 3  
가 100% VCM 가  
, 40 , 3  
. 15ppm , 22  
. 40 1 2 100% 가  
4 VCM Hill (1976), Cuddeback (1975), OSHA(1984)  
5 0 ) VCM (4 NIOSH  
. 5 22 40 40 VCM  
59.53%, 19.27%, VCM VCM  
21.20% Roh (2000) 16ppm Roh (2000) NIOSH(1994) VCM  
VCM 5 64.5%, 15.1%, 20.5% 2  
. 20ppm 22 5 , 1. 1ppm , 22 40  
0.44%(1.13 μg)가 22 15ppm 5 100%  
4 1 VCM  
16ppm 가 2. 5ppm , 22  
VCM 5 10%가 . 40 5  
1.6%±2.1% Roh NIOSH 1.05%(0.64 μg)가  
(2000) (1994) 가  
5 20ppm 22 20ppm VCM  
VCM 가 . 40 3. 10ppm , 22  
. 40 1 5ppm 5 40 , 1 100%  
5 2 10, 15, 20ppm 가 5 2  
, VCM 가 1ppm 가  
가 1.27 가  
가 가  
Yoon Nelson(1990) 1 가 4. 15ppm 22  
가 가 4.73 100%  
가 가 가 가 . 40  
Yoon Nelson(1990) vinylidene Cuddeback  
chloride 가 (1975), Severs Skoky(1975) Yoon  
(breakthrough volume)가 가 Nelson(1990)  
Foerst(1979) . 40 . 5. 20ppm 22 5  
10ppm VCM 22 20ppm VCM 0.44%(1.13 μg)가  
5 NIOSH No. 1007 4  
5ppm 가 . 40 1  
0.00% ~ 2.33% 8ppm 5 . 40 5ppm 100% 5

2  
6. 10%가  
NIOSH  
(1994) 22  
20ppm VCM 가  
. 40 1 5ppm  
1 5 가  
10, 15, 20ppm 3  
가  
22 20ppm VCM  
NIOSH No. 1007  
5 가  
40 5ppm VCM  
5 가  
10 ~ 20ppm VCM  
3

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가  
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