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Study on the Short Term Exposure Level (STEL) of the Benzene for the Tank Lorry Truck Drivers during Loading Process

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Abstract : Some of the petroleum products contain benzene which is well known as a confirmed human carcinogen. For example, gasoline products contain benzene ranging up to several percents by weight. High exposures to the benzene and other organic solvents would be likely to occur during intermittent tasks and or processes rather than continuous jobs such as sampling, repair, inspection, and loading/unloading jobs. The work time for these jobs is various. However, most of work time is very short and the representative time interval is 15 minutes. Thus, it is preferable to do exposure assessment for 15 minute time weighted average which is known as a short time exposure level(STEL) by ACGIH rather than for 8-hours TWA. It is particularly significant to the exposure monitoring for benzene since it has been known that the exposure rate plays an important role to provoke the leukemia. Due to the large variations, a number of processes/tasks, the traditional sampling technique for organic solvents with the use of the charcoal and sampling pumps is not appropriate. Limited number of samples can be obtained due to the shortage of sampling pumps. Passive samplers can eliminate these limitations. However, low sampling rates resulted in collection of small amount of the target analysts in the passive samplers. This is originated the nature of passive samplers. Field applications were made with use of passive samplers to compare with the charcoal tube methods for 15 minutes. Gasoline loading processes to the tank lorry trucks at the loading stations in the petroleum products storage area. Good agreements between the results of passive samplers and those of the charcoal tubes were achieved. However, it was found that special cautions were necessary during the analysis at very low concentration levels.

Key words: passive sampler, benzene, tank lorry driver, STEL

1. Introduction

A number of workers are exposed to various organic solvents at the petroleum and/or petroleum related industries. Typical exposure patterns at these facility-industries show different from those in the manufacturing industries. The 8-hour time weighted average(TWA) level shows very low in general. On the other hand, the short-term exposure level (STEL) shows relatively high. This is due to their job characteristics. Specific tasks that workers can be faced high exposure to the organic solvents are conducted periodically during the work shift, for example, sampling, checking, loading/unloading and testing the facility.

One of the typical tasks at the petroleum related industries is loading process of the petroleum products such as gasoline. Gasoline contains benzene ranging up to several percents by weight[1]. Benzene has been well known as a confirmed human carcinogen.[2] Also, recent studies of the statistical model and the intensity dependent model show that dose rate is more important rather than cumulative dose for the risk of leukemia due to benzene exposure.[3, 4] There is general agreement that benzene causes leukemia in highly exposed individuals [5] and the extent of the risk of leukemia with exposure to low concentrations of benzene has been debated [6-14].

The first step of industrial hygiene approach is to make exposure assessment. Traditional standard air sampling method to monitor workers exposure to organic solvents including benzene is collect samples using charcoal tube and air sampling pumps. This is good for the time integrated consecutive sampling during the whole work shift. However, it may not be practicable to collect sam-

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ples for a large number of workers for the short term, e.g. 15 min. due to limited resources. It also limits self monitoring. This implies that the traditional method has relatively low accessibility.

Passive samplers have been developed as an alternative. It has several advantages over the charcoal and sampling pumps. Reduced resources, simple procedure, low cost and easy acceptance by workers are known as main advantages. However, passive sampler has the decisive defect for short term exposure monitoring since its sampling rate is extremely low. The sampling rate of the passive samplers is approximately 1/10 compared to the active sampling method (air sampling pumps). This means that the collected amount of organic solvents in the sampling media (charcoal) may be too small to be quantitatively analyzed in the laboratory.

This study was designed to evaluate the passive samplers for monitoring workers short term exposure. The workers demand was regular and/or irregular self monitoring during their regular and/or irregular tasks. Tank lorry drivers exposures were monitored with use of both passive samplers and charcoal tubes during the loading processes for which high exposures were predicted since loading processes were conducted on the top of the tank lorry trucks by drivers themselves. On the other hand, unloading processes were simply conducted by connecting the flexible pipeline from the tank lorry to the gas station storage tank. Thus, this study was conducted for loading processes at an oil product storage station of a petroleum industry to provide validity and basic information for the use of passive samplers for short term exposure monitoring for the tank lorry truck drivers.

2. Method

Sampling and analysis was conducted based on the NIOSH method 1500.[15] Standard charcoal (SKC Anasorb) and personal air sampling pumps(LFS, GilAir sampler, Gilian Instrument, USA) were used for the traditional sampling technique. The 3M badges (OVM #3500 3M) were chosen for this study. Two charcoal tubes and two passive samplers were attached right and left sides in the breathing zone of each driver respectively during loading process. The flow rate of air sampling pumps was calibrated using the bubble meter. Charcoal and passive samples were analyzed using GC-FID(Model Agilent 6890N, Agilent Technologies, USA). Desorption efficiency was corrected by desorption efficiency tests for each batch. Sampling rate for the 3M badges were derived by calculation from the charcoal tube results.

3. Results

3.1. Benzene Exposure Levels

Total number of 35 personal samples was taken during the loading processes of gasoline products at the loading station in the petroleum product storage area. On the both the left and right side of the driver near the shoulder, a pair of charcoal tube and passive sampler was attached. Eleven components were analyzed including benzene, C5, C6, C7, C8 and MTBE. Airborne concentrations were extremely low compared to the occupational exposure limits, except for benzene and MTBE. Benzene is apparently significant to the industrial safety aspect. Thus, in this study, data was illustrated for benzene only. It was believed that benzene is the only significant chemical for workers exposure and environmental control during loading processes for gasoline products.

Since no true exposure concentrations were known, charcoal tube method was used as a reference. Figure 1 shows the average of left and right sides of exposure concentration by charcoal tubes. Typical log-normal data distribution was shown. Therefore, geometric mean (GM) and geometric standard deviation (GSD) were calculated for statistical parameters. GM and GSD by each sampling method and by left and right side were shown in Table 1. GM of average between right and left side by charcoal tubes were 0.77 ppm and 2.52 respectively. Airborne concentrations ranged from 0.1 to 5.1 ppm. By passive samplers, GM of average between right and left sides was 0.64 ppm which is 83% of that by the charcoal tubes. ACGIH TLV recommends 2.5 ppm for short term exposure limit (15 min-STEL) for benzene.

3.2. Charcoal tubes vs. passive samplers

Figures 2 and 3 show the agreements between charcoal tubes and passive samplers. In general, it shows

Table 1. GM and GSD of benzene exposure concentration of tank lorry truck drivers during loading processes for gasoline

Parameters	Charcoal tube		
	Left	Right	Average
GM	0.70	0.78	0.77
GSD	3.01	2.57	2.52
Range	0.02-4.85	0.10-5.33	0.09-5.09
	Passive sampler		
	Left	Right	Average
GM	0.63	0.51	0.64
GSD	2.76	4.20	2.80
Range	0.45-4.57	0.02-5.33	0.03-5.04

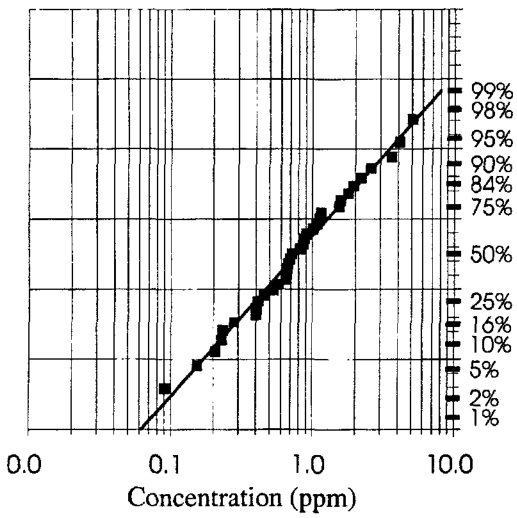

Fig 1. Benzene exposure data distribution of average between right and left side measured by charcoal tubes during loading processes of gasoline product to tank lorry.

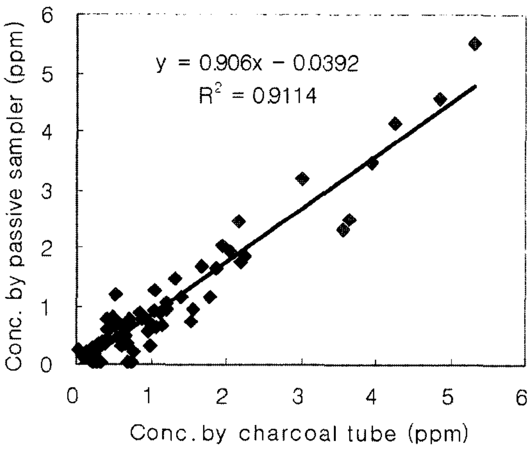

Fig. 2. Relationship of concentrations between by charcoal tubes and passive samplers taken all of left and right sides (N =70).

good agreements between the results of charcoal and passive samplers. However, the slopes of the regression equations show 0.906 and 0.905 respectively. This implies that exposures by passive samplers were underestimated for approximately 10% compared to those by charcoal tubes. It was assumed that this inconsistency was systematic error of passive samplers. Various factors can be considered during sampling processes such as temperature and humidity. However, it was believed that the environmental factors are not critical since the sampling were taken during normal weather conditions. It was assumed that the underestimation of the passive samplers was resulted from the tiny amount of samples

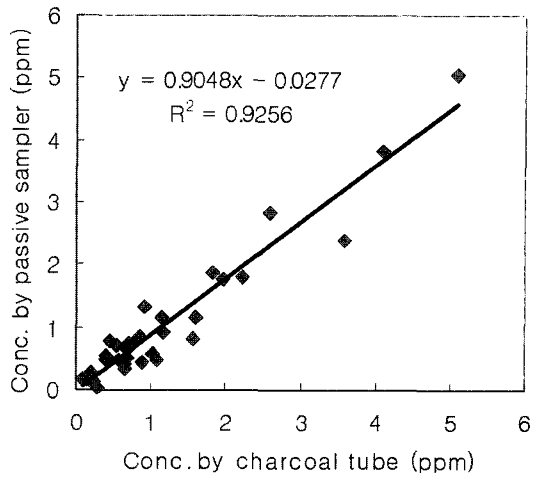

Fig. 3. Relationship of concentrations between by charcoal tubes and passive samplers for average between left and right sides (N=35).

taken on the charcoal bed in the passive samplers. Due to the intrinsic limitation of low sampling rate of passive samplers, only extremely small amount of target analytes can be adsorbed for short term sampling duration. In these ranges, the GC calibration curves does not show linear response. Thus, it tends to be underestimated for small amount of analytes during analysis by GC.

3.3. Right side vs. left side

For the assessment of workers' exposure, it was recommended to take personal sample at the breathing zone that is generally defined as a spherical area having a half diameter of 15 cm from the nose of the target worker. Thus, in industrial hygiene field, sampler was attached to the collar near the shoulder or the neck one of the left or right side. No report has been made for test of the agreement between the right and left sides. In this study, agreements were compared for the concentration levels taken between right and left sides by charcoal and passive samplers respectively. There were no statistical differences between right and left sides by paired t-test ($p<0.01$).

However, the slopes show greater than 1 both in figures 4 and 5 (1.07 for charcoal tubes and 1.18 for passive samplers). This implies that right sides show higher concentrations than left sides. It was assumed that most of tank lorry truck drivers are right-handedness and their work activities for loading processes are conducted in right side rather than left side. Therefore, it was resulted in that the concentrations in right sides were slightly higher than those in left sides.

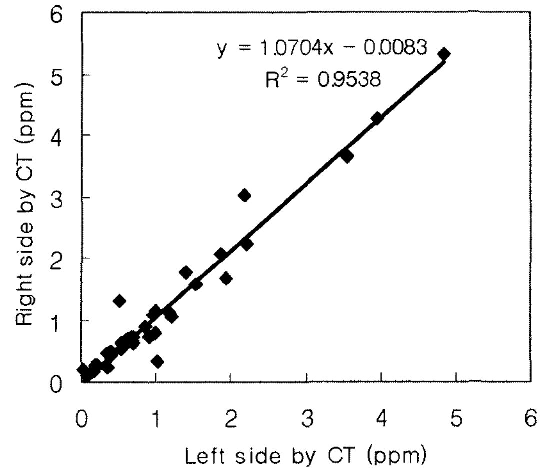

Fig. 4. Relationship of concentrations between at left and right sides by charcoal tubes (N=35).

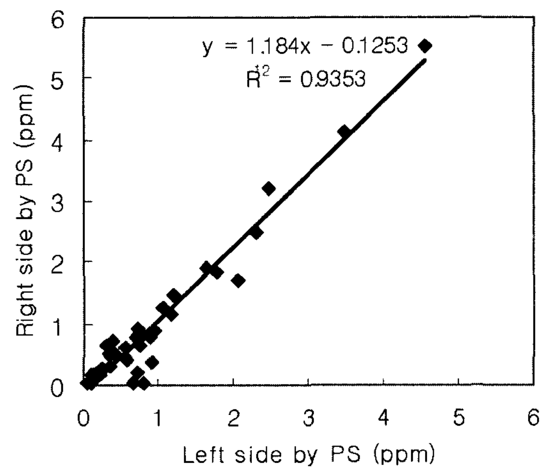

Fig. 5. Relationship of concentrations between at left and right sides by passive samplers (N=35).

4. Conclusion

Benzene exposure assessments were made for tank lorry drivers during loading processes of gasoline products at a petroleum storage stations. GM of benzene exposure during loading process of gasoline (approximately 15 minutes) was 0.77 ppm and GSD was 2.52. The range of exposure to benzene was from 0.1 to 5.1 ppm. Thus, the exposure level was below than the current ACGIH STEL of 2.5 ppm. Comparison was made between charcoal and passive samplers, and it was found there were generally good agreements between two sampling methods. However, it was revealed that the results of passive samplers were slightly underestimated compared to those of charcoal samplers. Since it is able to easily increase the sample size with the use of passive samplers, it would be possible to adopt them for self, irregular workers exposure assessment for benzene for tank lorry drivers. No significant differences were found between left and right side samples taken in the breathing zone.

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