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# Exposure to Vapors of Benzene and Other Aromatic Solvents in Tank Truck Loading and Delivery

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Benzene is an established human leukemogen (International Agency for Research on Cancer 1987 and 1989). Whereas current solvent products seldomly contain this insidious toxic chemical (Inoue et al. 1983; Kumai et al. 1983: Saito and Ikeda 1988), it is present in various petroleum distillates (Ikeda et al. 1984; Ikeda and Kasahara 1986; Kasahara et al. 1987), among which fuel gasoline is a typical product. Accordingly, attention has been paid to gasoline tank truck drivers and bulk marketing terminal personnel (Parkinson 1971; Sherwood 1972; Phillips and Jones 1978; Irving and Grumbles 1979; Gjörloff et al. 1982; Runion and Scott 1985; Halder et al. 1986; Berlin 1988) in addition to gasoline station attendants (Parkinson 1971; Nordlinder and Ramnäs 1983; Pandya et al. 1975; McDermott and Vos 1979; Halder et al. 1986; Berlin 1988), possibly because they are the groups of people with probable high risk of exposure to benzene.

The present study was initiated to examine the extent of occupational exposure of tank truck drivers to benzene and other aromatic solvents. Special references were made to the comparison of top and bottom loading of gasoline as a possible trigger for the reduction of solvent exposure at loading racks.

## MATERIALS AND METHODS

In total, 48 tank truck drivers were studied. They by themselves loaded petroleum products [mostly automobile gasoline, unleaded (Ikeda et al. 1984)], and drove the trucks to stations to unload the gasoline. About a half of the drivers (10 drivers each of top and bottom loading trucks) were examined only for the exposure during the loading operation at racks in a refinery, and the remaining half (13 and 15 drivers of

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top and bottom loading trucks, respectively) were monitored for an entire trip between the refinery terminal and the gasoline station including loading and unloading operation. Each driver was equipped with a diffusive sampler on the chest for the time period indicated. In addition, stationary sampling was conducted at 7 each of top and bottom loading racks. At a rack, one diffusive sampler each (3 samplers per rack) was placed on a nozzle of a loading hose, and at the entrance and exit end of the rack (about 1 m high from the ground and about 15 m apart between the two ends).

Diffusive samplers used had carbon cloth KF-1500 (Toyobo Co., Osaka, Japan) as absorbent, and samplers of the same type were employed for both personal and stationary sampling. After the termination of exposure, the solvents absorbed on carbon cloth were extracted with carbon disulfide (spiked with sec.-butylbenzene as an internal standard) and analyzed by means of automated FID gaschromatography (Hirayama and Ikeda 1979; Ikeda et al. 1984; Kasahara and Ikeda 1987). The lowest limits of the measurements for individual solvents were 0.01 ppm in the case of monitoring for 3 or more hours, and it was 0.1 ppm for 10 to 15 min exposure.

Both normal and log-normal distributions of the concentrations were assumed, and the difference of the means was examined by unpaired $t$-test.

## RESULTS AND DISCUSSION

The results of survey on the exposure of drivers to benzene and other solvents during loading operation are summarized in the top half of Table 1, and that of an entire trip in the bottom half (Table 1). The maximum exposure to benzene was 19 ppm in the case of top loading, and it was 5 ppm for bottom loading. The duration of operation (and therefore exposure) was however as short as 15 min or even less. The exposures to toluene, xylenes and ethylbenzene were more intense than that of benzene, in accordance with the fact that the concentrations of these aromatics in automobile gasoline are much higher than that of benzene (Ikeda et al. 1984), besides they are less volatile than benzene. The exposure during an entire trip of some 3 hours for delivery was quite low; for example, the time-weighted average exposure for benzene was well below 0.1 ppm (Table 1), suggesting that heavy exposure above 1 ppm took place only during loading and possibly unloading of gasoline.

Of particular interest is the fact that the exposure

Table 1. Solvent vapor exposures of tank truck drivers during loading and during a delivery trip

| Driver | No.[a] | Time[b] | Benzene[c] | Toluene[c] | Xylenes[c] | Ethylbenzene[c] |
|---|---|---|---|---|---|---|
| | | | M ± SD; maximum [ GM (GSD) ] | M ± SD; Maximum [ GM (GSD) ] | M ± SD; Maximum [ GM (GSD) ] | M ± SD; Maximum [ GM (GSD) ] |
| During loading of | | | | | | |
| Top loading truck | 10 | 14.1 ±4.7 | 5.20±5.54;19.2 [2.89 (4.09)] | 7.90±8.02;28.2 [3.58 (6.08)] | 8.29±6.62;21.8 [5.90 (2.50)] | 0.42±0.89; 2.2 [0.18 (3.61)] |
| Bottom loading truck | 10 | 13.5 ±2.9 | 1.56±1.67; 4.9* [0.75 (4.57)]* | 2.53±4.72;14.9† [0.47 (7.77)]* | 2.71±1.51; 6.1* [2.03 (3.02)]* | N.D. ; N.D. [0.1] |
| Total | 20 | 13.8 ±3.9 | 3.38±4.40;19.2 [1.47 (4.88)] | 5.22±6.97;28.2 [1.29 (8.60)] | 5.50±5.48;21.8 [3.47 (3.09)] | 0.21±0.65; 2.2 [0.14 (2.55)] |
| During a delivery trip in | | | | | | |
| Top loading truck | 13 | 164 ±41 | 0.07±0.07; 0.52 [0.10 (4.25)] | 0.84±0.38; 1.34 [0.73 (1.86)] | 0.26±0.35; 0.90 [0.06 (7.77)] | 0.05±0.13; 0.49 [0.01 (2.95)] |
| Bottom loading truck | 15 | 233 ±88 | 0.04±0.04; 0.40† [0.05 (3.06)]† | 0.53±0.43; 1.53 [0.32 (3.83)]* | 0.36±0.41; 1.37 [0.15 (5.09)] | 0.06±0.21; 0.80† [0.01 (3.11)] |
| Total | 28 | 201 ±78 | 0.05±0.06; 0.52 [0.07 (3.70)] | 0.67±0.43; 1.53 [0.47 (3.10)] | 0.31±0.38; 1.37 [0.10 (6.43)] | 0.06±0.17; 0.80 [0.06 (2.97)] |

For calculation of GM (GSD), N.D. (i.e., below the lowest limits of measurement of 0.1 ppm for 10-15 min monitoring, and 0.01 ppm for monitoring of 3 or more hours) was taken as if it were 0.1 ppm and 0.01 ppm, respectively. * and †; $p<0.05$ and $p<0.10$, respectively, for the difference between means. a Number of determinations. b Sampling time in min. c In ppm, except for GSD which is dimensionless.

Table 2. Solvent vapor concentrations at tank truck terminals

| Monitoring site | No.[a] | Benzene[b] | Toluene[b] | Xylenes[b] | Ethylbenzene[b] |
|---|---|---|---|---|---|
| | | M ± SD; Maximum [ GM (GSD) ] | M ± SD; Maximum [ GM (GSD) ] | M ± SD; Maximum [ GM (GSD) ] | M ± SD; Maximum [ GM (GSD) ] |
| At terminals for | | | | | |
| Top loading | 21 | 0.30±0.52; 2.12 [0.13 (3.97)] | 0.63±0.82; 3.84 [0.35 (3.35)] | 0.36±0.41; 1.68 [0.18 (4.01)] | 0.07±0.08; 0.32 [0.03 (3.76)] |
| Bottom loading | 21 | 0.03±0.04; 0.16** [0.02 (3.32)]** | 0.20±0.20; 0.77** [0.11 (4.06)]** | 0.22±0.24; 0.85** [0.11 (4.22)]** | 0.04±0.05; 0.16 [0.02 (3.03)]** |
| Total | 42 | 0.19±0.40; 2.12 [0.05 (4.84)] | 0.42±0.63; 3.84 [0.19 (4.16)] | 0.29±0.34; 1.68 [0.14 (4.14)] | 0.05±0.07; 0.32 [0.02 (3.43)] |
| At loading nozzle for | | | | | |
| Top loading | 7 | 0.75±0.72; 2.12 [0.42 (3.08)] | 1.14±1.27; 3.84 [0.70 (2.97)] | 0.80±0.42; 1.68 [0.72 (1.60)] | 0.11±0.11; 0.32 [0.06 (3.86)] |
| Bottom loading | 7 | 0.04±0.03; 0.09* [0.03 (2.43)]** | 0.12±0.10; 0.33* [0.09 (2.11)]** | 0.53±0.16; 0.85† [0.51 (1.35)]† | 0.05±0.06; 0.12 [0.03 (3.67)] |
| Total | 14 | 0.35±0.57; 2.12 [0.11 (5.57)] | 0.63±1.01; 3.84 [0.25 (4.02)] | 0.67±0.34; 1.68 [0.25 (4.02)] | 0.08±0.09; 0.32 [0.04 (3.83)] |

All measurements were by stationary sampling for 540 min. For calculation of GM (GSD), N.D. (i.e., below the lowest limit of measurement of 0.01 ppm) was taken as if it were 0.01 ppm. **, * and †; $p<0.01$, $p<0.05$ and $p<0.10$, respectively, for the difference between means. a Number of determinations. b In ppm, except for GSD which is dimensionless.

intensity varied depending on the type of loading. For example, benzene exposure was significantly ($p<0.05$ independent of assumption of normal or log-normal distribution) higher during top loading than during bottom loading (Table 1). This was also true for other solvent components. When the exposure during an entire trip was compared, however, the loading type-related difference was very small and only barely significant ($p<0.10$) even for benzene exposure.

Less solvent emission during bottom loading than top loading was confirmed by stationary sampling (Table 2). Although the levels as a whole was well below 1 ppm both at top and bottom loading terminals, the benzene concentration at the bottom loading racks was significantly ($p<0.01$) lower (about one-tenth) than that at the top loading racks, and this was also true for other solvents (in the top half of Table 2). The difference in concentration between top and bottom loading was even more large when the levels at loading nozzles were compared (in the bottom half of Table 2); the rates in the levels of benzene at the nozzles were about 1 to 20 for bottom and top loading. The duration of the presence of a driver at the nozzle was however very short, possibly 1 min or so.

The literature survey for the benzene or gasoline concentrations in truck loading terminals in the past shows that, according to the measurement in 1969 (Parkinson 1971), benzene concentration at bulk filling facilities for road transport was in a range of 0.2 to 3.3 ppm but it was higher (up to 9 ppm) when the gasoline was spiked with benzene at the concentrations of up to 33% (v/v). Sherwood (1972) reported that the loaders filling rail tankers were exposed to mean benzene concentrations of 1.6 to 2.5 ppm during 5 hour loading period. Similarly, the benzene concentrations measured by Phillips and Jones (1978) at various marketing terminals ranged up to 3 ppm. In a review, 0.3 to 3 ppm benzene was cited as the exposure level during gasoline loading on tank trucks (Holmberg and Lundberg 1985; presumably measured before 1979). In later studies, Runion and Scott (1985) summarized that over 90% of the benzene measures were below 0.5 ppm among 1,452 air samples collected at marketing terminals in the period of 1978-1983. In a close agreement, Halder and others (1986) observed that mean (±SD) benzene concentration in 183 air samples obtained at 5 gasoline distribution terminals was 0.3± 3 ppm. The present observation that benzene concentration at the terminal racks was 0.19 ppm as an arithmetic mean (or 0.05 ppm as a geometric mean) with a maximum of 2 ppm is on the line with the recent

reduction in benzene level at the terminal, and this level might be even lower than the values reported by Runion and Scott (1985) and Halder et al. (1986).

To the knowledge of the authors, the article by Berlin (1988) is the only report that describes the intensity of benzene exposure of tank truck drivers. According to the report, the average exposure was 0.4 ppm (4 ppm at maximum), with heavier exposure during loading (4.0 ppm as an average with a maximum of 46 ppm) and very little exposure (less than 0.11 ppm) during driving. The present findings as summarized in Table 1 suggest that the current exposure of the drivers are similar or slightly reduced. The rates among four aromatics of benzene, toluene, xylene and ethylbenzene are rather similar to the observation by Rappaport et al. (1987).

From the viewpoint of improvement in occupational and environment health, it is interesting to examine the possible difference in emission of benzene and other gasoline components between top and bottom loading. In the experience of Phillips and Jones (1978), bottom loading tended to give higher gasoline concentrations in filling terminal air than top loading, but the difference was not large enough to be statistically significant. Halder et al. (1986) found no significant difference in benzene concentration between top and bottom loading terminals. Irving and Grumbles (1979), however, observed twice as high concentration in top loading racks (2.29 ppm ± 0.25 ppm, as mean ± standard error) as in bottom loading ones (1.04 ppm ± 0.27 ppm). Holmberg and Lundberg (1985) also stated that top filling of tank trucks generally gave higher levels of exposure than bottom filling. The present observation (Tables 1 and 2) is apparently in the support of the latter opinion; the results suggest that more than 70% or more reduction in benzene exposure may be expected by bottom loading as compared with that by top loading.

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