TECHNICAL NOTE

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Toluene Distribution of Glue Sniffers' Biological Fluid Samples in Korea

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ABSTRACT: We have studied the distribution of toluene in glue sniffers' biological fluid samples by gas chromatography or gas chromatography/mass spectrometry. The determined toluene concentrations ranged from 0.1 to 40.3 mg/L in urine samples and from 0.1 to 74.7 mg/L in blood samples, respectively. Among the 120 urine samples, 61% of all cases ranged between 0.1 and 1.0 mg/L and 27% was between 1.0 and 5.0 mg/L, respectively. On the other hand, 39% and 46% of all 99 blood samples ranged between 0.1 and 1.0 mg/L, or 1.0 and 5.0 mg/L, respectively. In the fatal cases (36 cases), the distribution of toluene ranged from 0.3 to 40.5 mg/L in the blood samples.

KEYWORDS: forensic science, forensic toxicology, toluene, glue sniffing, inhalant abuse

Toluene is widely used as an industrial solvent as well as a chemical intermediary in various chemical engineering processes. In particular, toluene is used as a solvent in most of the chemical glues sold in Korea. It is well known that toluene has been implicated as a nervous system toxicant. Acute effects of toluene are similar to alcoholic intoxication in the sense of stimulation first and depression of the central nervous system later. Chronic abuse of toluene can lead to hepatomegaly and nephrotoxic symptoms. Exposure to high concentrations of this solvent may even cause death by sensitizing the myocardium (1–3).

In South Korea, methamphetamine (so-called hiropong) and marijuana are the main substances of abuse that induce hallucinations. However, these are very expensive and difficult to obtain because of tight prohibition by the government. Thus, toluene is one of the most frequently abused substances by teenagers, who inhale the vapor of commercial glues (bond) or thinners intentionally for its intoxicating effects. Actual incidents of glue sniffing in Korea have been reported at 10,000 to 20,000 annually, including around ten cases of accidental death. Since the rate of glue sniffing cases is growing due to the easy obtainability of glue, it is very important to determine the presence of toluene in biological fluid samples for forensic purposes (4).

Toluene in biological specimens has been measured by flame ionization, or by mass spectrometric detector of gas chromatography (GC/FID or GC/MS) with head space sampling (5–7).

In this study, we report the level of the concentrations of toluene in sniffers' biological fluid samples (mainly urine and blood samples).

Materials and Methods

Reagents—Toluene was purchased from Sigma Chemical (St. Louis, MO). The other reagents were purchased as analytical grade from Junsei Chemical Co. (Tokyo, Japan) All samples and reagents were dissolved (or diluted) with deionized water.

Standard solution—5000 mg/L toluene in methanol standard solution was diluted to appropriate concentrations by deionized water. Humic acid (HA) was dissolved to ethylacetate at proper concentrations.

Biological specimens—Urine and blood samples were collected from autopsies or arrestees who were suspected of glue sniffing. Samples were collected at the scene of capture in the cases of arrestees and transported to our lab in refrigerated condition without any pretreatment. The samples were delivered to our lab in less than 10 h from collection. In the cases of autopsies, only blood was collected to determine toluene level.

Instruments—We used a Varian 3400 gas chromatograph with a flame ionization detector (GC/FID) or an ion trap mass spectrometric detector (GC/MS, ITD model 800, Finnigan). We used either a stainless steel column [1.8 m by 0.3175 cm inside diameter (6 ft × 1/8 in.)] packed with 60/80 carbopack B/5%-carbowax 20 M (Supelco, Inc.) for GC/FID, or an AT-5 capillary column (30 m × 0.25 mm, Alltech. Assoc., Inc.) for GC/MS. The temperature for the packed column was programmed as follows: The temperature was set for 110°C initially and maintained for 3 min, then increased to 180°C at a rate of 10°C/min and kept there for 10 min. The carrier helium gas rate was 22 mL/min throughout the experiment. With the capillary column, the column temperature was kept constant at 130°C. The injector and transfer line temperatures were 220°C and 270°C, respectively. The toluene concentrations were routinely deter-

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mined by the GC/FID system equipped with a capillary column unless the gas chromatogram was too complicated to identify the toluene peak. In that case, we employed the GC/MS method to confirm the toluene peak.

Head space sampling—A head space vial was filled with 2 mL sodium citrate solution (4.8 g citric acid, 13.2 g sodium citrate, and 14.7 g dextrose/L), 1 mL of blood or urine, and 50 μL of internal standard (0.5% isobutanol). After the vial was warmed in a water bath at 55°C for 20 min, 250 μL of head space air was automatically injected into a GC/FID or GC/MS.

Results and Discussion

Analysis of toluene—We identified toluene in the biological specimens by GC and GC/MS. The calibration curve was obtained with diluted standard solutions, with concentrations adjusted to 0.1, 0.5, 1.0, 2.0, 5.0, 10.0, 20.0, 30.0, and 40.0 mg/L by a head sampling procedures in the experimental section. The relationship between peak ratio and concentration was linear between 0.1 mg/L and 40.0 mg/L. A typical regression equation was $y = 0.236x + 0.001$ with a correlation coefficient of 0.999. The data were usually obtained from an average of three trials and the coefficient of variation was 5% to 10% depending on sample conditions. The gas chromatograms and mass spectrum of toluene in glue sniffers' biological fluids with head space sampling procedures are shown in Figs. 1 and 2. We show the base peak at $m/z = 91$ actually rising from the seven-membered ring ion and molecular weight peak at $m/z = 92$.

Distribution of toluene in glue sniffers' biological samples—The representative distributions of toluene in biological specimens are shown in Figs. 3 and 4. Approximately 100 samples (120 for urine and 99 for blood samples) from arrestees who were suspected for glue sniffing between the years 1994 and 1996 were tested. The determined toluene concentrations ranged from 0 to 22.3 mg/L in urine samples and from the 0.2 to 74.7 mg/L in blood samples, respectively. In the cases of urine, 61% of the total specimens ranged between 0.1 and 1.0 mg/L and 27% of those ranged between 1.0 and 5.0 mg/L. However, only 12% of these were shown to be above 5.0 mg/L of toluene concentration (Fig. 3). Despite the fact that around

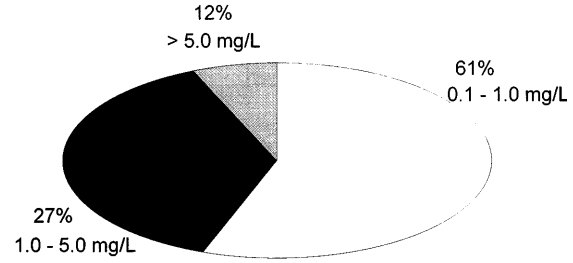

FIG. 3—*Distribution of toluene concentrations in glue sniffers' urine. From 120 samples collected from arrestees for toluene intoxication between 1994 and 1996.*

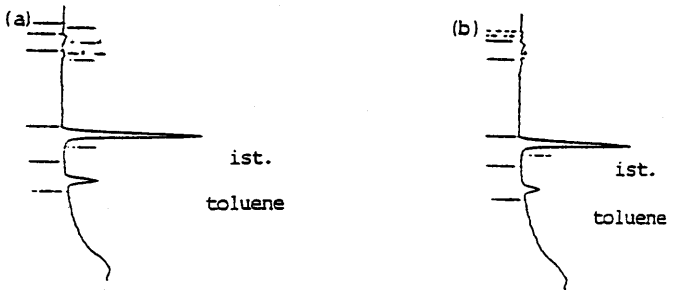

FIG. 1—*Gas chromatograms of toluene in glue sniffers' biological fluids: (a) blood sample; (b) urine sample. GC/FID system employed. ist = internal standard.*

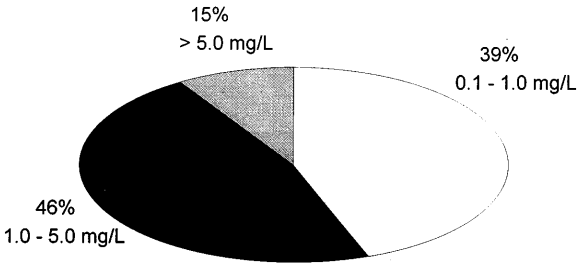

FIG. 4—*Distribution of toluene concentrations in glue sniffers' blood. From 99 samples collected from arrestees for toluene intoxication between 1994 and 1996.*

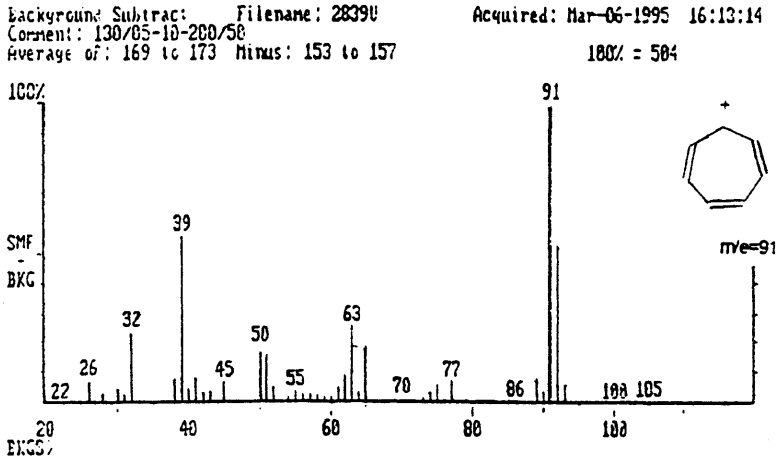

FIG. 2—*Mass spectrum of toluene peak from glue sniffer's blood gas chromatogram. GC/Ma system employed.*

TABLE 1—*Distribution of toluene in glue sniffers' urine and blood.*

No.	Toluene Conc.*		Age	Sex
	Urine	Blood		
1	0.2	0.2	28	M
2	1.2	0.2	17	M
3	. . .†	5.8	22	M
4	. . .†	4.4	22	M
5	0.6	1.3	29	M
6	. . .†	0.9	18	M
7	0.4	3.9	17	M
8	15.1	58.7	16	M
9	22.3	74.7	18	M
10	0.1	0.4	17	M
11	2.2	2.7	17	M
12	0.4	1.4	16	M
13	0.2	3.0	17	M
14	0.2	2.4	18	M
15	. . .†	2.1	18	M

* Units: mg/L.
† Below 0.1 mg/L.

TABLE 2—*Toluene concentration in blood specimens in cases of glue sniffing related death.*

No.	Toluene Conc.	Age	Sex
1	60.2	30	M
2	7.8	23	M
3	2.7	17	M
4	2.0	48	M
5	4.7	20	M
6	18.6	22	F
7	3.5	13	M
8	1.6	15	M
9	6.4	16	M
10	11.0	18	M
11	0.2	20	M
12	1.0	15	F
13	0.6	15	F
14	0.3	30	M
15	6.3	17	M
16	0.6	18	M
17	17.8	24	M
18	9.1	16	F
19	1.4	16	M
20	0.4	17	M
21	4.3	17	M
22	4.9	16	M
23	3.1	15	M
24	0.5	22	M
25	12.1	18	M
26	1.6	44	M
27	2.9	19	M
28	21.6	16	M
29	14.7	15	M
30	1.3	25	M
31	7.0	22	M
32	5.0	25	M
33	7.0	16	M
34	0.5	14	M
35	0.3	16	M
36	4.8	23	M

10% of samples possessed less than 0.1 mg/L of toluene, those data were categorized in the 0.1 to 1.0 mg/mL range because the trace toluene concentration above the detection limits (0.01 mg/L) of our method was detected in all of those samples. In the cases of blood samples, 46% of the all cases (99 cases) ranged between 1.0 and 5.0 mg/L and 39% of those ranged between 0.1 and 1.0 mg/L of toluene concentration. Fifteen percent of those were shown to be above 5.0 mg/L of toluene concentration (Fig. 4). More than 0.2 mg/L of toluene concentration was detected in all of the blood samples tested. Some of the representative data are listed in Table 1. The concentration in blood was higher than that in urine in the identical person's specimens except for one case in 15. When the urine toluene level is found to be less than 1 mg/L, we need additional experiments on the blood samples to confirm intoxication. Bonnichen et al. (8) and Kuper et al. (9) reported urine concentrations of 0 to 5.0 mg/L and blood concentrations of 0.3 to 13.0 mg/L in 22 such persons who were either hospitalized or arrested while intoxicated. No relationships between the toluene concentrations determined and other factors such as age, sex and body weight were revealed with our data. Such relationships might be caused by uncertainties due to the amount of toluene inhaled and the time that passed from the intoxication and collection process at the scene of action by policemen. Data are not listed, but none of the controlled samples (samples from non-intoxicated persons) have toluene concentrations.

In the cases of death after glue inhalation, the blood toluene levels were indicated in the range of 0.3 to 60.2 mg/L (average 6.9 mg/L Table 2). Baselt et al. (10) reported blood toluene concentrations of 10 to 20 mg/L (average 13 mg/L) with lethal cases of toluene intoxication. The average toluene concentrations of lethal cases in our data are smaller than other literature data. These results indicate that the death cases in our research may be related not only to toluene intoxication, but also to disease and weather and among other factors.

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