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Short Communication

Tentative Criteria for Assessing Workers Exposure to Toluene by Urinary Toluene Screening

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Abstract: This study assessed screening thresholds for determining workers exposure to toluene (Tol) by urinary Tol (Tol-U) and proposed applicable criteria for on-site settings. Participants' urine samples (n = 21) were collected at the end of the workday during the latter half of a week and the Tol-U concentration was assayed. Simultaneously, each worker's exposure dose to Tol in the breathing zone during work, Tol-TWA (time-weighted average), was measured. Tentative criteria were proposed. Level I, less than Tol-U 38 μg/l, has the least chance of exceeding Tol-OEL 50 ppm (occupational exposure limit for Tol recommended by the Japan Society for Occupational Health), probability 95% <. Level II, Tol-U 38–60 μg/l, has a low possibility of exceeding Tol-OEL. Level III, Tol-U 60–110 μg/l, has a high possibility of exceeding Tol-OEL. Level IV, more than Tol-U 110 μg/l, clearly exceeds Tol-OEL, probability 95% <.

Key words: Urinary toluene, Biological monitoring, Toluene exposure, Criteria for assessing

In Japan, workers handling toluene (Tol) are required by law to undergo examination of urinary hippuric acid (HA-U). Food-derived HA, however, is present in urine even in the general population[1, 2], and the upper normal limit of HA-U that can be considered an indication of Tol exposure is approximately 0.6 g/g-creatinine[3]. This corresponds to approximately 40 ppm Tol in the air[3]. However, the occupational exposure limit (OEL) for Tol recommended by the Japan Society for Occupational Health (JSOH) is 50 ppm.

Therefore, JSOH recommended a Tol-U concentration of 60 μg/l as an OEL of Tol based on biological monitoring (Tol-Bio-OEL) in 2000[4]. At on-site settings, however, some conditions and procedures for Tol-U measurement might not match the recommendation. This study assessed the screening thresholds for determining workers exposure to Tol by Tol-U and proposed criteria applicable to on-site settings.

Twenty-one healthy workers handling Tol at a printing company agreed to participate in the study after a precise explanation of the purpose.

Participants' urine samples were collected at the end of the daily work in the latter half of a week. Each urine sample was placed in the top of a 10 ml volume screw cap bottle with Teflon® liner packing and kept in cold storage (ca. 3˚C) until measurement (within several days). The procedure for handling urine samples in this study differed from the JSOH recommendation[5] because we set a priority on meeting the actual conditions on-site. In the JSOH recommendation, urine should be sampled less than 2 h before finishing work and sealed in vials for GC, however, we confirmed that the Tol level is maintained for at least one week using our procedures[6].

The assay of Tol-U was conducted with HS-SPME-GC (Head Space-Solid Phase Micro Extraction-Gas Chromatography) method[7]. Urine samples (5 ml) were

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Table 1. Mean value and 90% confidence intervals of Tol-U calculated by four groups divided according to the distribution of Tol-TWA

Group*	Workers	Tol-TWA range (ppm)	Tol-TWA mean (ppm)	Tol-U mean (μg/l)	Tol-U Upper 5% (μg/l)	Tol-U Lower 5% (μg/l)
1	n=5	3.2 − 6.3	4.5	5.0	7.6	2.5
2	n=5	22.1 − 35.0	29.6	39.0	58.4	19.7
3	n=8	45.8 − 67.4	56.0	59.5	95.3	23.6
4	n=3	87.4 − 107.6	97.6	159.3	232.0	86.7
				r=0.969†	r=0.979†	r=0.934†

*According to the distribution of Tol-TWA, workers were divided into four groups.
†Correlation coefficient between Tol-TWA and each Tol-U.

placed in 10 ml volume vials, mixed with 50 μl methanol (because of the standard solution dissolved in methanol) and 1 g sodium chloride (NaCl). The vials were sealed with a septum with a Teflon® liner for HS-GC. The contents were thoroughly mixed and left for 1 h at room temperature (25˚C). SPME fiber was inserted into the HS of the vial, and extraction was performed for 5 min while the sample solution was stirred using a stirrer. The SPME fiber was immediately injected into the GC and held for 2 min.

Simultaneously, each worker's exposure dose to Tol in the breathing zone during work, Tol-TWA (time-weighted average), was measured using diffusive samplers (3M #3500 Organic Vapor Monitor Minnesota, USA). The assay of diffusive samplers was performed according to the manufacturer's analysis guide (3M 1992). After the elution with 1.5 ml of carbon disulfide, GC was performed using a Shimadzu GC-8A (Kyoto, Japan) with a flame ionization detector (FID) under the following conditions: column, DB WAX (J & W California, USA), 30 m × 0.53 mm I.D., 1.5 μm (film thickness); carrier, He 10 ml/min; make up, N_2 40 ml/min; oven, 55˚C; injection / detector, 150˚C.

As the Tol standard solution, a standard reagent for water quality analysis (Wako Pure Chemical Osaka, Japan), fibers with polydimethylsiloxane film thickness of 100 μm (SUPELCO No.5-7300 Pennsylvania, USA) were used.

The Tol-TWA of workers ranged from 3–108 ppm (n = 21). Tol-TWA and Tol-U among workers exposed to Tol showed a linear relation (r = 0.918) and we obtained a regression line with 0 intercept; y (Tol-U) = 1.37x (Tol-TWA). Using this equation, we estimated 69 μg/l of Tol-U corresponding to the 50 ppm occupational exposure limit of Tol (Tol-OEL), which is close to the JSOH recommendation (Tol-Bio-OEL 60 μg/l).

To assess the screening levels of Tol exposure by Tol-U, we estimated the individual 90% Tol-U limits according to Ogata's method[3]. Because the residual plots of Tol-U spread as Tol-TWA level increased, we pursued regression lines that did not show equal variance.

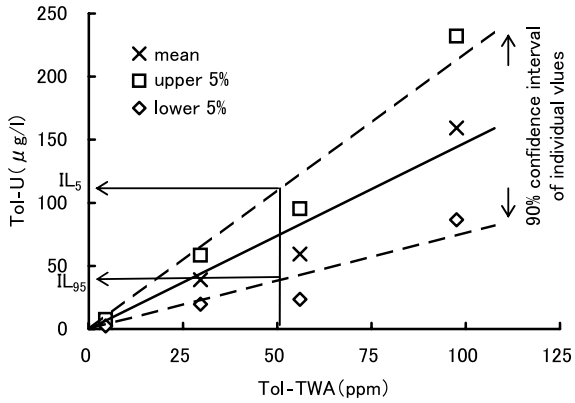

Fig. 1. Regression lines of individual Tol-U 90% predicitive limits.
IL_5 indicates that workers with a Tol-U level greater than 110 μg/l are expected to have been exposed to Tol more than Tol-OEL (50 ppm) with a 95% probability. IL_{95} indicates that workers with a Tol-U level less than 38 μg/l are expected to have been exposed to Tol less than Tol-OEL (50 ppm) with 95% probability.

First, according to the distribution of Tol-TWA, workers were divided into four groups. Second, mean value and 90% confidence intervals of Tol-U of each group were calculated (Table 1). Then, the regression lines of upper 5% and lower 5% limits with 0 intercept were estimated (Fig. 1). From the regression lines we estimated the upper (IL_5) and lower (IL_{95}) limits of Tol-U corresponding to Tol-OEL, which were 110 μg/l and 38 μg/l respectively. IL_5 indicates that workers with a Tol-U level greater than 110 μg/l are expected to have been exposed to Tol more than Tol-OEL with a 95% probability. IL_{95} indicates that workers with a Tol-U level less than 38 μg/l are expected to have been exposed to Tol less than Tol-OEL with 95% probability.

From our findings we proposed tentative criteria for evaluation of Tol exposure by Tol-U (Table 2). Level I,

Table 2. Tentative criteria for assessing workers exposure to toluene by Tol-U screening

Exposure	Tol-U(μg/l)	Possibility exceeding Tol-OEL 50ppm	Exposure reduction countermeasures
Level I	<38	Least (probability 95%<)	No additional actions are required but routine monitoring is recommended
Level II	38 ≦ Tol-U<60	Low	Should be taken if levels exceed Tol-OEL
Level III	60 ≦ Tol-U<110	High	Countermeasures are necessary
Level IV	110 ≦	Exceeding (probability 95%<)	Must be taken immediately

less than Tol-U 38 μg/l, has least chance of exceeding Tol-OEL (probability 95% <). Level II, Tol-U 38-60 μg/l, has a low possibility of exceeding Tol-OEL. Level III, Tol-U 60-110 μg/l, has a high possibility of exceeding Tol-OEL. Level IV, more than Tol-U 110 μg/l, clearly exceeds Tol-OEL (probability 95% <).

These criteria can be applied to the health management of workers who handle Tol. In case of Level I findings, there are no additional actions required but routine monitoring is recommended. In case of Level II, Tol exposure concentration (Tol-TWA) should be measured, and exposure reduction countermeasures should be taken if levels exceed Tol-OEL (50 ppm). In case of Level III or higher, Tol exposure reduction countermeasures are necessary and these must be taken immediately when in cases showing Level IV.

We proposed tentative criteria for assessing Tol exposure by Tol-U monitoring on-site. The criteria may become useful guidelines for health care for workers handling Tol. However, larger scale field tests are required to confirm the feasibility of the method from various aspects because the series examined in this study was small.

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