Arh. hig. rada toksikol., **30** *(1979) suppl. pp. 483–488.*

EVALUATION OF OCCUPATIONAL EXPOSURE TO XYLENE BY BLOOD, EXHALED AIR AND URINE ANALYSIS

K. ENGSTRÖM[1], K. HUSMAN[2], P. PFÄFFLI[3] and V. RIIHIMÄKI[3]

Turku Regional Institute of Occupational Health, Turku[1], Kuopio Regional Institute of Occupational Health, Kuopio[2], Department of Industrial Hygiene and Toxicology, Institute of Occupational Health, Helsinki[3], Finland

ABSTRACT

Occupational exposure to xylene was measured in the breathing zone of 15 painters during three consecutive workdays. Xylene concentrations in blood and exhaled air and methylhippuric acid excretion in urine were simultaneously monitored to determine possibilities to evaluate exposure by biological tests. A good correlation to the time-weighted average of xylene exposure was obtained for urinary methylhippuric acid concentration at the end of the workday, while xylene concentrations in exhaled air and blood sampled after the workday correlated poorly with the exposure of the preceding day. The amount of methylhippuric acid in a morning sample at the end of the work week correlated with the mean exposure of the three preceding days.

Biological monitoring of workers exposed to various industrial chemicals may play an important role, either in detecting excessive exposure or in discovering biological disturbances when they are still reversible or have not yet caused any health impairment. Biological tests are being increasingly used because of deeper understanding of pharmacokinetics and rapid improvement in analytical techniques. This kind of monitoring may also offer advantages over monitoring the air of the workplace, as it takes into consideration absorption by all the routes (not only through the lungs) and enables consideration of individual differences in susceptibility to the chemical differences in the rate of absorption, distribution, biotransformation, and excretion. Conventional specimens, which have been used for biological monitoring are blood, exhaled air and urine. The majority of volatile organic substances are partially eliminated unchanged with the expired air and partially metabolized into more polar derivatives, which are excreted in the urine. Thus, theoretically, all three specimens can be employed, when the exposure of workers to organic solvents is being evaluated. In the present study we investigated the possibility of finding a parameter which could be used in the biological control of occupational exposure of painters. Xylene was chosen as the object of investigation and its

concentration in ambient air, blood and exhaled air, as well as the methylhippuric acid concentration in the urine of 15 painters were analyzed. The relationships between the different parameters (blood, exhaled air and urine) and the time--weighted average of xylene exposure in the ambient air were estimated and their applicability in occupational health practice was discussed.

SUBJECTS AND METHODS

The occupational xylene exposure of 15 painters (1 female and 14 males, aged 18 to 63 years) was measured by collecting air from the breathing zone through charcoal sampling tubes for periods of half an hour over the whole workday in the course of three consecutive workdays (Wednesday to Friday). The absorbed xylene was desorbed with dimethylformamide and analyzed by gas chromatography. For each day time-weighted averages (TWAs) were calculated.

Simultaneously, biological monitoring was carried out by measuring the concentration of xylene in the blood and in the exhaled air as well as the concentration of methylhippuric acid in the urine. The time-points for sampling after the workshift were as follows; for blood: 5, 95, 185 and 965 min (only Wednesday), for exhaled air: 1–3, 90, 180, and 960 min (Wednesday and Thursday) and for urine: 10 min, 4, 8 and 15 h (Wednesday, Thursday and Friday). In addition, one urine sample at lunch-break and exhaled air samples at 2-hour intervals were collected during the workshift. The methods of collection and analysis are described in more detail elsewhere[1,2].

RESULTS AND DISCUSSION

Exhaled air

Exhaled air concentration during the workshift in relation to the corresponding ambient air levels are presented in Figure 1. The mean xylene concentrations in the exhaled air amounted to 8% (range 1 to 27%, $N = 75$) of the mean level in the ambient air sample, collected during the preceding half--hour period. The great variability in the results shows that exhaled air sampling during the day only gives us a rough estimation of the momentary concentration in the ambient air. Marked fluctuations in airborne concentrations seem to influence the results; the peak concentration in inspired air in Figure 1 a for example, is not reflected in the xylene concentration of a corresponding exhaled air sample. Factors like body constitution and lung ventilation may also affect this relation.

The concentrations of xylene in exhaled air samples taken at given intervals after termination of exposure correlated poorly to the xylene concentration in ambient air of the preceding workday. The best correlation ($r = 0.63$) was obtained when the sampling was performed about 3 hours after termination of exposure. Exhaled air values for different time-points grouped according to the xylene exposure of the previous workday are presented in Table 1. The mean concentrations of xylene in all groups decreased to about one third of the peak

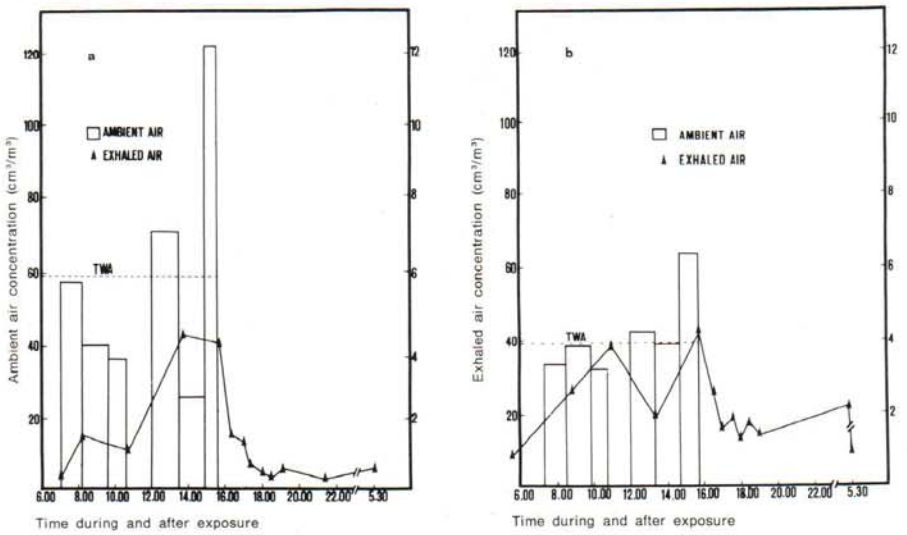

FIG. 1 – Xylene concentrations (cm^3/m^3) in ambient air and in exhaled air of two subjects (a and b) during and after exposure.

value in the course of 1 to 2 hours and thereafter more slowly over the 16 hours follow-up period. Although there is a natural increase in the mean xylene concentration from one group to another, the great overlapping between the groups makes the method unsuitable for obtaining exact information about the actual exposure level. This drawback can be ascribed to the rapid decrease in the exhaled air concentrations immediately after cessation of exposure, which makes the time of sampling very critical in relation to the variability of exposure. Analytical uncertainties are another problem especially for the later time-points in the postexposure period, because the fraction of the absorbed dose eliminated by the lungs is very small[3].

TABLE 1
Postexposure xylene concentrations in exhaled air (μg/l).

Time after exposure (min)	TWA[a] xylene concentration during work					
	1–20 ppm (N = 12)		21–40 ppm (N = 13)		41–70 ppm (N = 5)	
	Mean	Range	Mean	Range	Mean	Range
1–3	4.6	0.4–8.2	9.8	3.3–18.9	17.8	12.7–45.6
90	2.0	0.2–4.9	3.5	1.0– 8.9	3.5	3.2– 4.0
180	1.5	0.1–2.6	2.4	0.7– 6.1	3.4	1.4– 6.1
960	1.8	<0.1–5.7	2.2	0.5– 8.5	4.8	0.7–15.6

[a]TWA = Time-weighted average.

Blood

The postexposure xylene concentrations in the blood are presented in Table 2. The best correlations with the time-weighted average of xylene concentration were obtained for the 95 min sample ($r = 0.77$) and the 185 min sample

TABLE 2
Postexposure xylene concentrations in blood (μg/l).

Time after exposure (min)	TWA[a] xylene concentration during work					
	1–20 ppm (N = 5)		21–40 ppm (N = 5)		41–70 ppm (N = 5)	
	Mean	Range	Mean	Range	Mean	Range
5	256	70–460	434	330–620	874	310–1 360
95	72	30–140	218	160–330	248	190– 370
185	44	20– 70	120	40–250	168	110– 270
965	30	10– 50	60	40– 80	73	40– 160

[a]TWA = Time-weighted average.

($r = 0.75$). The blood results seem to be less sensitive to external influence than the exhaled air values. This difference can be explained by the difficulty in obtaining reproducible and representative exhaled air samples.

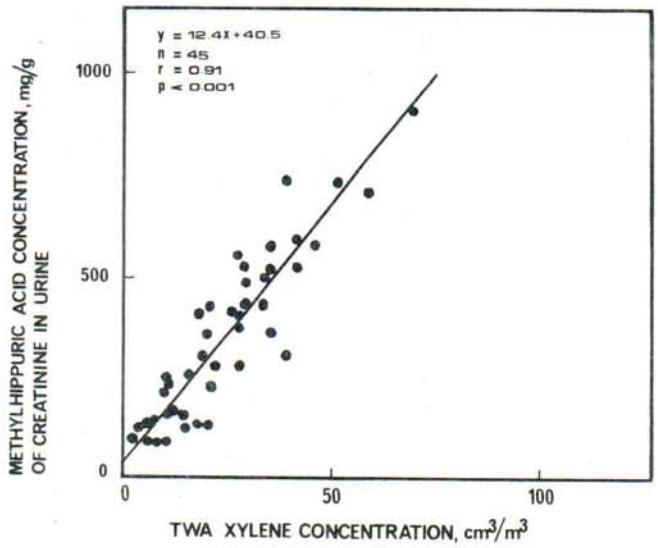

FIG. 2 – Correlation between urinary methylhippuric acid concentration (mg/g of creatinine) and the time-weighted average (TWA) of xylene exposure (cm^3/m^3).

Urine

A high positive correlation was observed between the methylhippuric acid concentration (mg/g creatinine) in samples representing the urine of the last 4 to 5 hours of the workshift and the time-weighted average of xylene exposure ($r = 0.91$) (Figure 2). For samples representing the urine excreted in the course of the whole workshift, the corresponding correlation gave a similar coefficient ($r = 0.92$). The distribution of the results is larger if the metabolite concentrations are expressed as milligrams per liter, adjusted to a density of 1.018 ($r = 0.86$), and still larger if they are expressed as milligrams per hour ($r = 0.80$).

The urinary excretion of methylhippuric acid on the first morning (Saturday) after a work week correlated highly with the mean TWA of xylene exposure during the three preceding days ($r = 0.89$) (Figure 3). Poor correlation existed however between the TWA xylene exposure of Friday and the methylhippuric acid concentration in the urine the next morning.

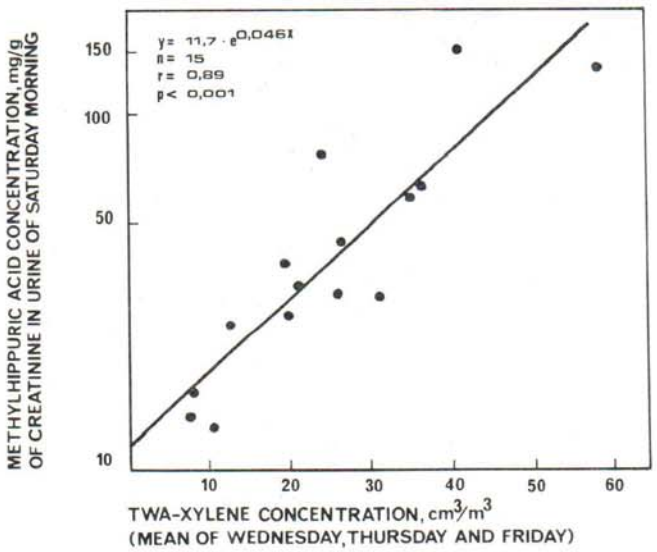

FIG. 3 – Correlation between urinary methylhippuric acid concentration (mg/g of creatinine) of the Saturday morning sample and the time-weighted average (TWA) of xylene exposure cm^3/m^3, mean of Wednesday, Thursday and Friday. Log-lin scale.

On the basis of this study, we recommend the use of urine samples collected at the end of the workday for evaluating the average xylene exposure during the preceding day. The exhaled air results show too great a distribution and the blood has a disadvantage of involving greater inconvenience than the sampling of breath or urine. The concentration of methylhippuric acid in a morning sample at the end of the work week provides, on the other hand, a rough estimation of the xylene load of the preceding week.

REFERENCES

1. *Engström, K., Husman, K. and Rantanen, J.* Measurement of toluene and xylene metabolites by gas chromatography. Int. Arch. Occup. Environ. Health, **36** (1976) 153–160.
2. *Engström, K., Husman, K. and Riihimäki, V.* Percutaneous absorption of m-xylene in man. Int. Arch. Occup. Environ. Health, **39** (1977) 181–189.
3. *Šedivec, V. and Flek, J.* The absorption, metabolism, and excretion of xylenes in man. Int. Arch. Occup. Environ. Health, **37** (1976) 205–217.