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### Quantitative determination of airborne 2,4-toluene diisocyanate

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Toluene diisocyanate (TDI), generally used as a mixture of its 2,4- and 2,6-isomers (80:20), is the isocyanate most widely used in the polyurethane industry<sup>1,2</sup>. Exposure to high concentrations of TDI may cause serious respiratory disorders; isocyanate vapours or particles may irritate the eyes<sup>3</sup> and mucous membranes and, if inhaled, cause coughing, dyspnoea and asthma, even at low concentrations in air<sup>4</sup>.

It has been suggested that inhaled TDI vapour produces an allergic state in exposed individuals and that this forms the basis for an asthmatic-like syndrome<sup>5,6</sup>. Such individuals become unable to work where TDI is used and this has created a significant medical problem<sup>7-9</sup>. Consequently, the American Conference of Governmental Industrial Hygienists proposed a lower threshold limit value (TLV) of 0.002 ppm, corresponding to 0.014 mg/m<sup>3</sup> in air<sup>10</sup>. Monitoring this TLV necessitates the development of a more sensitive method.

The sampling and analysis of diisocyanates in air have been the subject of several studies<sup>11</sup>; most methods for the determination of organic aromatic isocyanates are based on the original spectrophotometric procedure of Marcali<sup>12,13</sup>. However, the poor specificity and sensitivity at lower levels limit the use of this method. At present high-performance liquid chromatography (HPLC) seems to be the best technique<sup>10,14-17</sup>.

We propose method involving mass fragmentography to obtain better specificity, especially when the detection of low concentrations of TDI in the working atmosphere is required. The method described here is based on the hydrolysis of 2,4-TDI in an acidic medium and subsequent analysis of the corresponding 2,4-toluenediamine (2,4-TDNH<sub>2</sub>).

## EXPERIMENTAL

### Reagents

2,4-Diaminotoluene, 1,3-phenylene diamine and N,N-dimethylformamide dimethyl acetal (DFA-DMA) were obtained from Fluka (Buchs, Switzerland). Methylene chloride, acetonitrile and methanol were purchased from Carlo Erba (Milan, Italy).

### Gas chromatography-mass fragmentography

An LKB 2091 low-resolution mass spectrometer equipped with a gas chromatograph was used. The chromatographic conditions were as follows: glass column, 2 m × 2 mm I.D., packed with 3% OV-1 on Gas-Chrom Q (100–120 mesh); oven temperature, 250°C; nitrogen flow-rate, 30 ml/min. The gas chromatographic-mass spectrometric conditions were the same as above, except carrier gas, helium; ion source temperature, 260°C; energy ionization beam, 70 eV; trap current, 50  $\mu$ A. Measurements were performed by focusing the mass spectrometer on the ion at  $m/z$  232.

### Air sampling

Air sampling was carried out in a small room in which were simulated the environmental working conditions of manual painting, using a paint containing 1% of TDI. The operative conditions were previously tested in order to ensure, during the painting and the subsequent natural drying, atmospheric concentrations of monomer lower than 0.1 mg/m<sup>3</sup>.

To evaluate experimental airborne concentrations of TDI, air was sampled at a flow-rate of 0.6 l/min through two porous fritted glass bubblers in series containing 0.4 *N* hydrochloric acid as absorbing medium (30 ml for each bubbler). The air was drawn through by a DuPont 4000 personal sampling pump at constant flow, previously calibrated with a soap-film flow meter.

### Extraction procedure and derivative formation

In order to evaluate the recovery after extraction and derivatization procedures, amounts of 2,4-TDNH<sub>2</sub> ranging from 0.05 to 100 ng were added to 20 ml of 0.4 *N* hydrochloric acid. These acidic solutions, after alkalization with 6 *N* sodium hydroxide solution, were extracted twice with 25 ml of methylene chloride. The or-

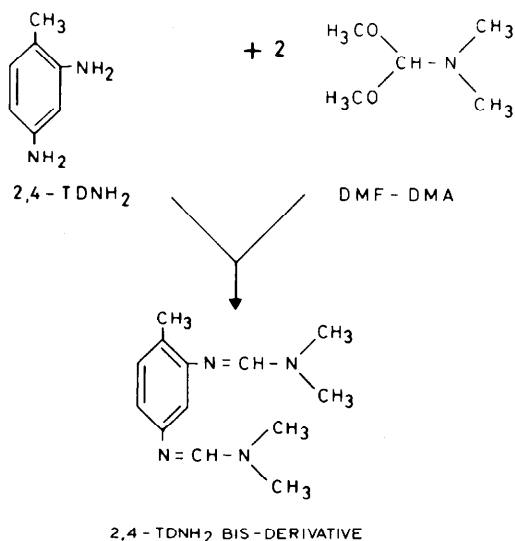


Fig. 1. Derivatization pattern of 2,4-TDNH<sub>2</sub> with N,N-dimethylformamide dimethyl acetal (DFA-DMA).

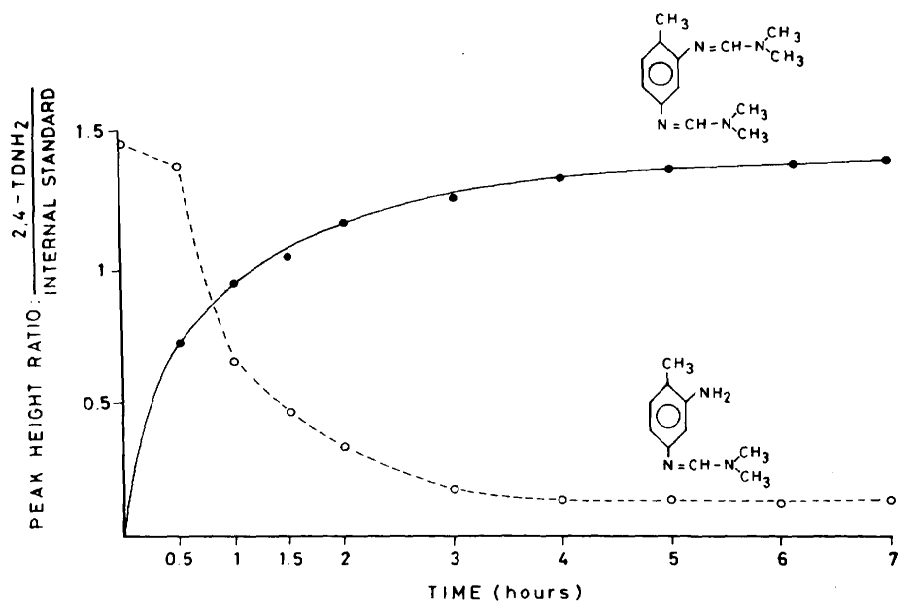


Fig. 2. Effect of reaction time on formation of 2,4-TDNH<sub>2</sub> mono- and bisderivatives.

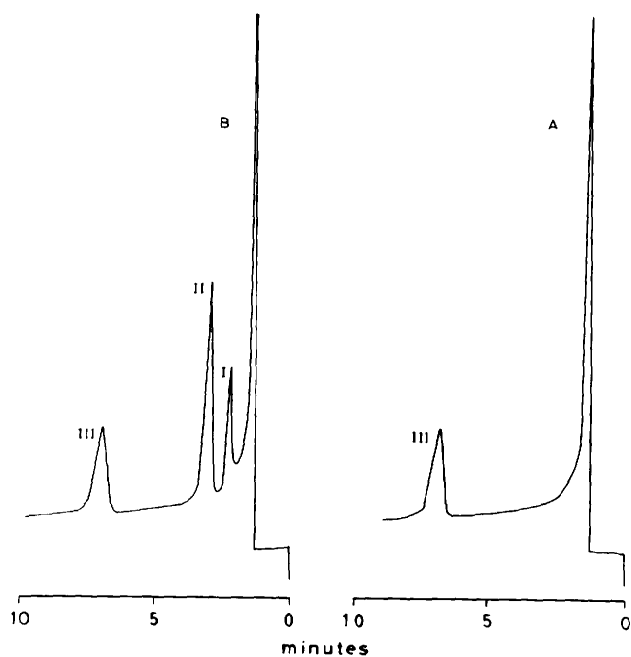


Fig. 3. Gas chromatograms: (A) control sample added with chlorpromazine as internal standard (III); (B) reaction mixture of (I) 2,4-TDNH<sub>2</sub> mono-derivative, (II) 2,4-TDNH<sub>2</sub> bis-derivative and (III) chlorpromazine.

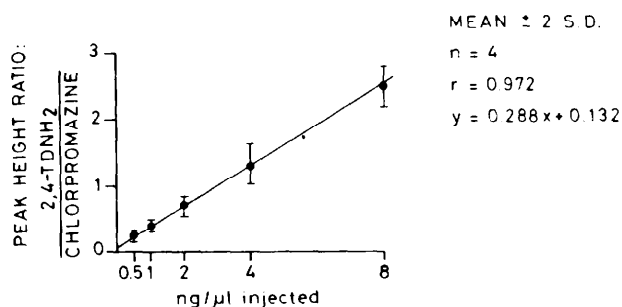


Fig. 4. External calibration graph for 2,4-TDNH<sub>2</sub> bis-derivative.

ganic phase was evaporated to dryness, the residue was dissolved in 0.3 ml of acetonitrile and the solution was transferred in Reacti-Vials containing amounts of anhydrous sodium sulphate, 50  $\mu$ l of DMF-DMA were added and the samples were reacted for 5 h at 100°C. The derivatization reaction is shown in Fig. 1.

After derivatization, the samples were dried under a gentle flow of air and dissolved in 100  $\mu$ l of methanol containing chlorpromazine as internal standard.

Fig. 2 shows the effect of reaction time on the formation of the 2,4-bis-derivative. Constant maximum levels were obtained after 5 h, but small amounts of the mono-derivative were always present. Derivative levels were evaluated from the peak-height ratio of the products and the internal standard using gas chromatography (Fig. 3).

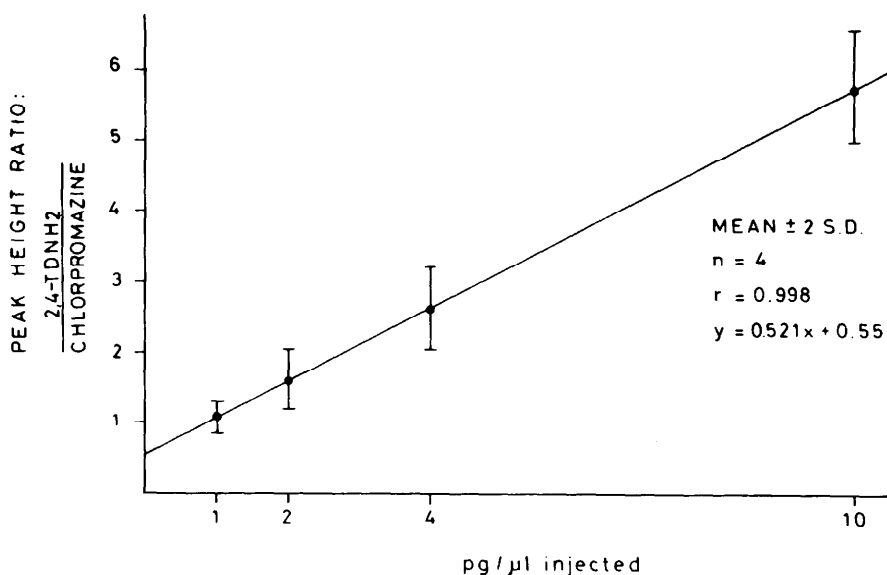


Fig. 5. Internal calibration graph for 2,4-TDNH<sub>2</sub> bis-derivative.

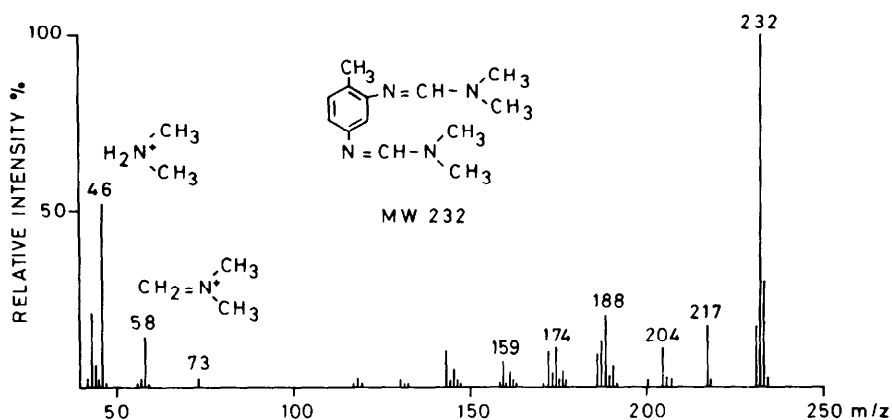


Fig. 6. Mass spectrum of 2,4-TDNH<sub>2</sub> bis-derivative.

### Measurement

A range of standard solutions were derivatized and analysed by mass fragmentography after adding an equal amount of chlorpromazine. A calibration graph was prepared by injecting 1- $\mu$ l aliquots of these solutions (Fig. 4).

The ratio of the peak height of the 2,4-TDNH<sub>2</sub> bis-derivative to that chlorpromazine was linear in a range 0.5–8 ng/ $\mu$ l injected. Fig. 5 shows the calibration graph obtained by adding known amounts, ranging from 0.05 to 0.5 ng of 2,4-TDNH<sub>2</sub>, to 20 ml of the acidic solution and processing them as described under *Extraction procedure and derivative formation*.

### Recovery studies

The recovery evaluated after the whole procedure of extraction and derivatization, for 100, 50 and 20 ng added to 20 ml of the acidic solution, was 70%. In order to obtain similar recoveries with amounts of 10 ng and less, it is necessary to add an amount of 1,3-phenyldiamine, which has a high chemical affinity with 2,4-TDNH<sub>2</sub>.

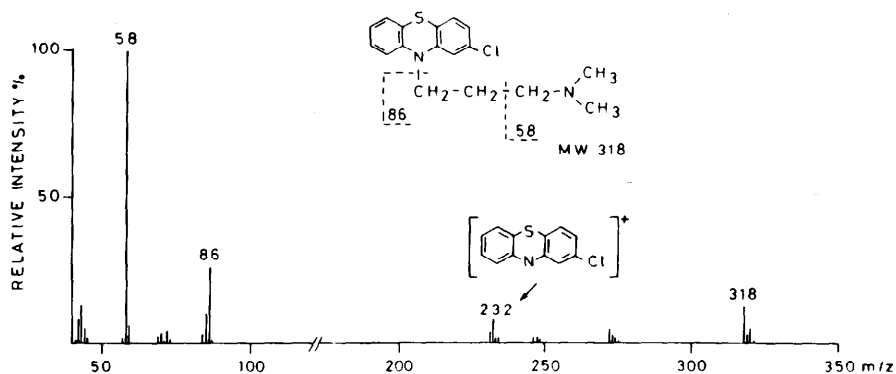


Fig. 7. Mass spectrum of chlorpromazine.

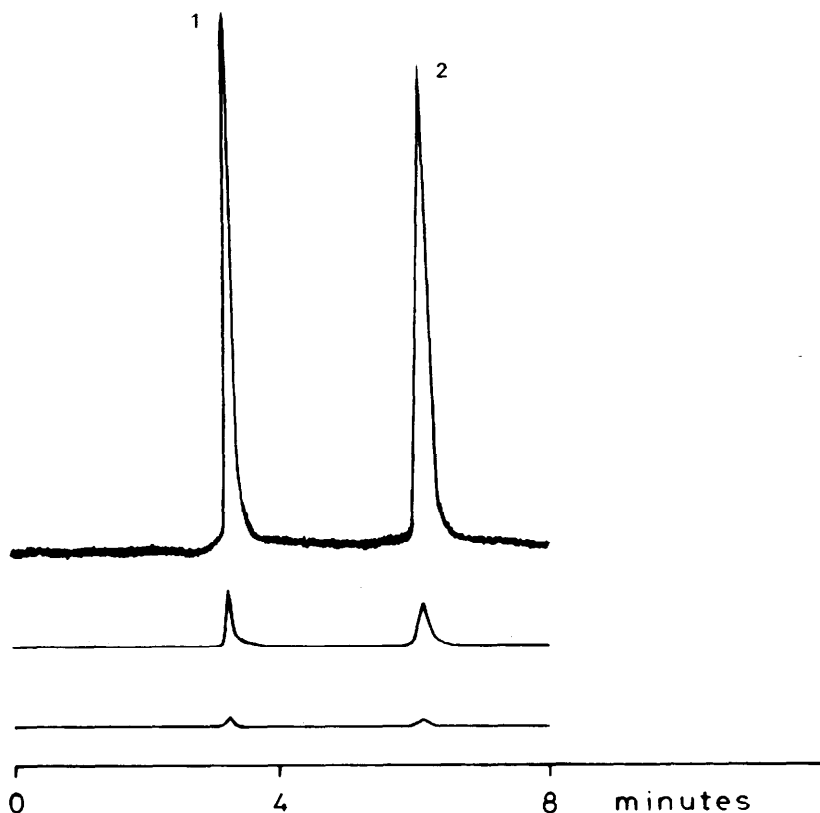


Fig. 8. Mass fragmentogram obtained from (1) 2,4-TDNH<sub>2</sub> bis-derivative and (2) chlorpromazine as internal standard. The instrument was focused on the ion at  $m/z$  232. The detection limit is 200 pg/ $\mu$ l injected.

## RESULTS AND DISCUSSION

The mass spectrum of the 2,4-TDNH<sub>2</sub> bis-derivative is shown in Fig. 6; the molecular ion, also the base peak, is at  $m/z$  232. The main fragment ions of the compound are also indicated. The mass spectrum of chlorpromazine, used as the internal standard, is shown in Fig. 7.

TABLE I

COMPARISON BETWEEN THE VALUES OBTAINED BY SPECTROPHOTOMETRIC AND MASS FRAGMENTOGRAPHIC METHODS

Sample	Marcali method (mg/m <sup>3</sup> )	Mass fragmentography (mg/m <sup>3</sup> )
A	0.230	0.230
B	0.160	0.160
C	n.d.	0.086
D	n.d.	0.060

For the mass fragmentographic analysis, the instrument was focused on the peak at  $m/z$  232, corresponding to the base peak of 2,4-TDNH<sub>2</sub> bis-derivative and to a fragment ion of chlorpromazine. A typical mass fragmentographic trace of a standard preparation is shown in Fig. 8; the instrumental detection limit is of 500 pg.

To evaluate the validity of this method, some samples collected as described under *Air sampling*, were analysed using the above method and by the Marcali spectrophotometric method. Good agreement between the results was obtained. Moreover, the proposed method allows the determination of small amounts of TDI not detectable by the spectrophotometric method (Table I).

In conclusion, because of its high sensitivity and specificity, we consider mass fragmentography to be an alternative technique for TDI determination at the TLV level.

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