

the world.¹ Around 50% of the formaldehyde produced is used to make resins for adhesives in the manufacture of particleboard and plywood.² The most common health effects of low-level formaldehyde inhalation are eye, nose, and upper respiratory irritation.³ Moreover, it was reported that formaldehyde can induce tumors in rodents,^{4,5} and it is recognized as a suspected human carcinogen.⁶

Acknowledging the toxic effects of formaldehyde, the American Conference of Governmental Industrial Hygienists (ACGIH) lowered the threshold limit values (TLVs) from 1 ppm for an 8-hour time-weighted average (TWA) and 2 ppm for a 15-minute short-term exposure limit (STEL) to a 0.3 ppm ceiling in 1991.⁷ The permissible exposure limit (PEL) enforced by US Occupational Safety and Health Administration (OSHA) was also lowered from 1 ppm to 0.75 ppm for an 8-hour TWA, but the STEL remains at 2 ppm.^{8,9} Many countries have proposed a maximum recommended concentration for indoor formaldehyde. It is 0.1 ppm in the United States, Germany, and the Netherlands; and 0.12 ppm in Denmark. However, the World Health Organization (WHO) submitted a lower recommendation of 0.08 ppm in 1990.^{10,11}

Because large amounts of formaldehyde-containing wooden products are used for interior decoration and furniture, plus the tight sealing and central air conditioning of modern buildings, indoor formaldehyde concentrations can accumulate to high levels. In Taiwan, because the interior decoration business has been booming, workers may have experienced considerable formaldehyde exposure during the decorating period, and also large groups of the general public may be exposed to low levels of formaldehyde in their homes. Because of humans long-term indoor presence, nowadays controlling indoor air problems is essential. Because of these concerns, we conducted this study in 1995 to measure the indoor formaldehyde exposure of workers and residents.

MATERIAL AND METHODS

New decorated houses in metropolitan Taipei area were selected as our study population. With the consent of workers and house owners, a total of 34 houses were included in this study. The first air sampling in

each series of samples was performed during the decoration period. Subsequent samplings were continued for up to 6 months after completion. Air sampling was performed for a period of approximately 7 hours (typically 9 AM to 4 PM) each time. For comparison, background data, including the indoor and outdoor environments, were measured. Information about housing characteristics, such as the location and type of dwelling and the presence and type of air conditioning, were recorded.

Formaldehyde was collected by a passive diffusive method and analyzed by a colorimetric method.¹² An SKC passive bubbler was chosen for sampling. Formaldehyde was absorbed into a 0.05% aqueous solution of 3-methyl-2-benzothiazolinone hydrazone hydrochloride (MBTH) contained in a sampler consisting of a glass vial with a septum cap that contains a Knudsen disk. During air sampling, the vial was inverted to establish contact between the absorbing liquid and the Knudsen disk. Formaldehyde passed from the ambient atmosphere into the MBTH solution through the Knudsen disk at a constant sampling rate of approximately 11.6 ml/min (which varied in each batch and was provided by the supplier). After collection, the resulting azine was oxidized by a ferric chloride sulfamic acid solution to form a blue cation dye in acidic medium. The concentration of the blue cation was measured by spectrophotometry at 628 nm. The air concentration of formaldehyde was computed from the amount of formaldehyde collected divided by the product of the diffusion rate and the time exposure. NIOSH method 3500, using an air-sampling pump and analysis by the chromotropic acid method, was used as the reference method.¹³ The flow rate was calibrated both before and after the sampling period for each active sampling. Temperature, air velocity, and relative humidity measurements were taken at each sampling time. All measured concentrations were corrected to standard conditions of 25 °C and 760 mm Hg.

RESULTS AND DISCUSSION

Table 1 and Fig. 1 show the results for different samplings. The highest formaldehyde concentrations in indoor air were found during the construction period, and