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Elevated Exposure to Nitrogen Dioxide During Food Preparation: Results from a Cooking Laboratory

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Lung cancer incidence has been increasing significantly in recent decades in Chinese societies (Du et al. 1996; Gao et al. 1987; Ger et al. 1993; Ger et al. 1992; Ko et al. 1977; Liu et al. 1993; Wang et al. 1996). It has been one of the most common cancers that are leading cause of death in Taiwan since 1980's (Ger et al. 1993), and the increase of lung cancer mortality is the greatest among all malignant neoplasms in Taiwan since 1950's.(Tay 1988). The principal risk factor of lung cancer is cigarette smoking (Chen et al. 1990; Liu 1992), which elevates approximately 2.2-fold risk of lung cancer to smokers (Liu 1992). However, the significantly greater incidence of lung cancer, especially adenocarcinoma, among Chinese women compared to that of the Western women is worth investigating (Ger et al. 1993). This type of cancer is less strongly related to smoking, which is consistent to a significantly low prevalence of smoking (5.2%) in Chinese woman population (Yen and Pan 2000). Epidemiological studies show the higher incidence of lung cancer among Chinese women may be attributed to traditional Chinese cooking (Du et al. 1996, Gao et al. 1987, Ger et al. 1993, Ger et al. 1982, Ko et al. 1997, Liu et al. 1993, McLennan et al. 1977, Wang et al. 1996). Studies on cooks, bakers and pastrycooks also indicate that a higher incidence of lung cancer may occur (Carstensen et al. 1988, Coggon et al. 1989, Jahn et al. 1999, Kjærheim et al. 1993, Teschke et al. 1989). Thus many studies were carried out to investigate the correlation between lung cancer and the type of cooking oils, the type of cooking (frying, stir frying and deep frying) as well as cooking fuels (Gao et al 1987, Ger et al. 1993, Ko et al. 1997, Metayer et al. 2002, Teschke et al. 1989, Wu et al. 1999). The conclusion remains to be unclear as well as controversial. For example, some studies show that the type of cooking could significantly influence lung cancer incidence while others don't (Gao et al. 1987; Ger et al. 1992;Ger et al. 1993; Ko et al. 1977; Ko et al. 1997; Liu et al. 1993; Wang et al. 1996). Chronic lung diseases are a potential risk factor as well (Ger et al. 1993). This indicates that agents produced during cooking, which could affect respiratory systems, may be as crucial as carcinogen in the development of lung cancer, especially when their amount is enormous. Nitrogen dioxide is a well-known ambient pollutant that is generated during food preparation whenever the temperature is high. The ambient nitric oxides are also demonstrated to relate to airway obstruction, and acute NO_2 exposure may increase the airway reactivity (Jammes et al. 1998; Kienast et al. 1995; Chauhan et al. 2003). This study aims to

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assess the possible acute exposure to NO_2 during food preparation by measuring personal exposure of a class of students in food preparation laboratory.

MATERIALS AND METHODS

A diffusive passive NO_2 sampler was assembled and utilized to estimate NO_2 exposure levels. The sampler was evaluated at varying NO_2 concentrations, ranging from 17 ~ 165 ppb, in a testing atmosphere. The collected NO_2 was quantified by employing the Griess-Saltzman reaction at 25 °C for 15 minutes following the measurement of absorbance at 540 nm. The average recovery of the sampler is 99.9% with a standard deviation of 6.5% and the overall accuracy is 13.1%. The method detection limit for sodium nitrate solution was 5.2×10^{-5} mM as defined three standard deviation of quadruple blank measurements. The sampling rate of this passive device was experimentally determined to be 1.63 mL/min; and therefore, the overall detection limit was estimated to be 3.1 ppb•min. The evaluation of the lowest testing concentration of NO_2 proved that the ambient NO_2 concentration would be precisely quantified with a sampling time of three hours if the NO_2 concentration was higher than 135 ppb. The experimental procedure was detailed elsewhere (Lin et al, 2000). A total of 40 students in a food and beverage management-major class in a mid-sized technical college were recruited to wear the sampler during their weekly food preparation laboratory session. Each student was provide a sampler and was asked to record the beginning and ending time of the sampling period. In addition, a data log was provided for each participant to provide their personal information (name, age, gender) and to record the task they performed during the sampling period. Samples were collected right at the end of the class and analyzed within the same day using a spectrophotometer. A total of 33 students with appropriately handled samples as well as the comprehensive record were used to evaluate the personal exposure to NO_2.

RESULTS AND DISCUSSION

The average NO_2 concentration was 608 ppb with a standard deviation of 272 ppb, ranging from 300 to 1502 ppb. The distribution of personal exposure to NO_2 is illustrated in Figure 1. The average exposure of the lowest group was 332 ppb with a standard deviation of 33.2 ppb and, more than 50% of students were exposed to 400 ~ 800 ppb during the experimental session. As shown (Table 1), the reported personal exposure to nitrogen dioxide in Taipei and Los Angeles were 52.8 ppb (geometric mean) (Chen 2002) and 37.6 ppb (mean)(Spengler et al. 1994), respectively. The personal exposure to NO_2 for students, workers, and housewives in Italy were 13.0, 23.5 and 21.3 ppb, respectively (Gallelli et al. 2002). The personal exposure to NO_2 significantly depended on individual's life pattern (Chen 2002). Apparently, the reported scenario here was much worse, although it was lower than the PEL value defined by the US OSHA (3 ppm). Compared to ambient air quality standard for NO_2, the result was higher than the one-hour limit for NO_2 (250 ppb) and much higher than the annual average standard (50 ppb). In the US, the only NO_2-related regulation for indoor

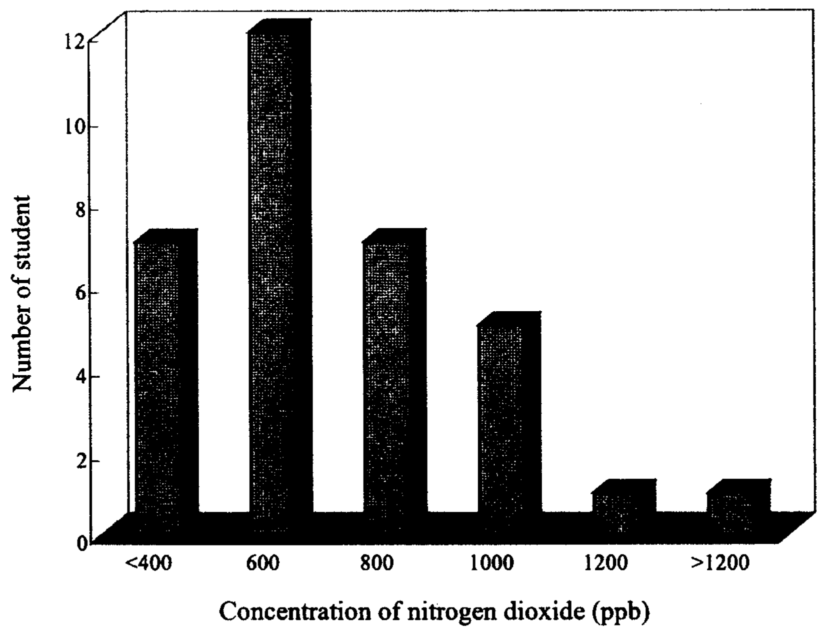

Figure 1 Distribution of personal exposure to nitrogen dioxide

environment was for that of ice rinks, in which the NO_2 concentration must not exceed 250 ppb in order to protect public health. The ambient NO_2 levels in large cities are usually lower than the ambient standards with an exception for Taipei City (Table 1)(Baldasano et al. 2003). The NO_2 concentration in ice arenas with traditional resurfacers may be higher than 250 ppb (Pennanaen et al. 2003; Hedberg et al. 1989, Rosenlund and Bluhm 1999). The NO_2 concentration in the cooking laboratory was expected much higher than the ambient levels, and adverse health effects from exposure to high NO_2 level seem likely among the exposed group. At very high concentration (above 650 ppb), NO_2 has been linked with adverse health effects among sensitive subpopulations. The symptoms owing to exposure to nitrogen dioxide include cough, hemoptysis, dyspnea and chest pain that may remain latent from a period of some hours to two days (Hedberg et al. 1989). An acute respiratory illness outbreak among adolescent hockey players was reported (Karlson-Stiber et al. 1996). In the incidence, twenty players needed medical assistance and two were admitted to intensive care units (Karlson-Stiber et al. 1996). The following epidemiological study found that, for adolescent hockey players, bronchial responsiveness could occur at levels above 1000 ppb in healthy subjects and at levels above 100 ppb in asthmatic subjects (Rosenlend and Bluhm 1999). Nitrogen dioxide may induce the inflammatory mediators from airway epithelial cells that could lead to the pathogenesis of airway disease (Kienast et al 1995). The higher the personal exposure to NO_2, the more serious the virus-induced asthma exacerbations in children will turn to be even when the nitrogen dioxide levels were much lower than ambient standards (Chauhan et al 2003).

Table 1. Nitrogen dioxide levels in the ambient air (ppb).

Area	Sampling Type	NO_2	Reference
Santiago, Chile	Indoor	35.8	Rojas-Bracho et al. (2002)
	Outdoor	36.9	
	Personal	25.9	
Genoa, Italy	Indoor/bedroom	13.2	Gallelli et al. (2002)
	Indoor/kitchen	25.0	
	Personal/students	13.0	
	Personal/workers	23.5	
	Personal/houewives	21.3	
Taipei, Taiwan	Personal	52.8	Chen (2002)
Hamburg, Germany	Indoor	8.0	Cyrys et al. (2000)
Erfurt, Germany	Indoor	9.0	
Finland	Indoor/Ice Rink	176.5	Pennanen et al. (1998)
Australia	Indoor/bedroom	7.3	Garrett et al. (1999)
	Indoor/livingroom	9.1	
	Indoor/kitchen	8.1	
Boston, USA	Indoor/ice rink (November)	506.5	Yoon et al. (1996)
Los Angeles, USA	Outdoor	38.3	Spengler et al. (1994)
	Indoor/bedroom	27.2	
	Personal	37.2	
Taipei, Taiwan	Indoor	37.7	Hung (1993)
	Outdoor	56.2	
Taipei, Taiwan	Indoor/kitchen	71.9	Shiu (1988)
	Indoor/livingroom	56.1	
	Indoor/bedroom	46.5	
	Outdoor	59.6	
Hsinchu, Taiwan	Personal	608.0	This Study

The most important indoor source of NO_2 is from kitchens (Garrett et al. 1999). During cooking hours, the residents' personal exposure levels of NO_2 will increase to 3 –5 fold to their weekly average levels NO_2 (Noy et al. 1990). The estimated emission factor of NO_2 for natural gas kitchen stoves is 61 ± 18 μg/kcal (De Nevers 2000). Based on the average oxygen content of 6% in exhaust, 0.33 mmol of NO_2 will be produced if one mole of CH_4 is burned (De Nevers 2000). In general, one family consumes approximately 40 m^3 of natural gas every month in Taiwan, and 15 m^3 (≅20 mole) of that is burned in kitchens. The emission rate of NO_2 is 2.7 mg/min during food preparation if the food preparation time is assumed to be 90 minutes every day. During the food preparation, the level of NO_2 in kitchens will critically depend on the ventilation rate, and can be estimated using the following equation:

$$C_t = \frac{G - (G - QC_0)e^{-\frac{Q(t-t_0)}{V}}}{Q}, \qquad (1)$$

where G is the emission rate, Q the ventilation rate, V the room volume, C_0 the concentration at time t_0, and C_t the concentration at time t. The concentrations of NO_2 at varying air exchange rate (AER) (0, 1, 2, 4, 10 hr^{-1}) in a kitchen of 20 m^3 can be calculated; and, after 30 minutes, they may reach approximately 2150, 1690, 1360, 930, 430 ppb, respectively. Almost everyone drinks boiled water instead of tap water in Taiwan. Thus, it's worthy noted that there is almost no ventilation in kitchens while people are boiling water, and this will produce extremely high concentration of NO_2 in kitchen. As professional cooks spend much longer time in the kitchen than general population, higher cumulative exposure may be expected. Because of the adverse effects and large labor population involved, occupational exposures to NO_2 among professional cooks warrant further examination.

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