



Investigation of volatile organic compounds in office buildings in Bangkok, Thailand: Concentrations, sources, and occupant symptoms

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ABSTRACT

To conserve energy, office buildings with air-conditioning systems in Thailand are operated with a tight thermal envelope. This leads to low fresh-air ventilation rates and is thought to be partly responsible for the sick building syndrome symptoms reported by occupants. The objectives of this study are to measure concentrations and to determine sources of 13 volatile organic compounds (VOCs) in office buildings with air-conditioning systems in the business area of Bangkok. Indoor and outdoor air samples from 17 buildings were collected on Tenax-TA™ sorbent tubes and analyzed for individual VOCs by thermal desorption-gas chromatography/mass spectrometry (TD–GC/MS). Building ventilation was measured with a constant injection technique using hexafluorobenzene as a tracer gas. The results show that the VOC concentrations varied significantly among the studied buildings. The two most dominant VOCs were toluene and limonene with average concentrations of 110 and 60.5 $\mu\text{g m}^{-3}$, respectively. A Wilcoxon sum rank test indicated that the indoor concentrations of aromatic compounds and limonene were statistically higher than outdoor concentrations at the 0.05 level, while the indoor concentrations of chlorinated compounds were not. Indoor emission factors of toluene and limonene were found to be highest with the average values of 80.9 and 18.9 $\mu\text{g m}^{-2} \text{h}^{-1}$, respectively. Principal component analysis was applied to the emission factors of 13 VOCs, producing three components based on source similarities. Furthermore, a questionnaire survey investigation and field measurements of building air exchange pointed to indoor air complaints related to inadequate ventilation.

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1. Introduction

Land and commercial properties in Bangkok, the capital city of Thailand, have been increasingly developed during the past three decades [8]. More than 730 buildings with greater than 15 floors are located in the inner Bangkok Metropolitan. The urban-city's land use has been changed from naturally-ventilated shop houses to high-rise commercial buildings with air-conditioning system. Because approximately 60% of the total amount of energy used in these commercial buildings is due to air-conditioning or chilling systems, it is imperative that building operators reduce the loss of conditioned air by making buildings airtight. The reduced fresh air intake results in deterioration of indoor air quality as reported by a questionnaire survey on indoor environmental problems that was

distributed in some of Bangkok's office buildings that had adopted energy conservation measures according to the Energy Conservation Promotion Act, B.E. 2535 [34]. However, few studies have been conducted to investigate the contamination of indoor air in office buildings in Thailand, particularly for VOCs. There was the study of Ongwandee et al. [36], investigating concentrations of formaldehyde and acetaldehyde in 12 office buildings in Bangkok. The mean indoor concentrations were 35.5 and 17.1 $\mu\text{g m}^{-3}$, respectively. Indoor to outdoor (I/O) ratios of the concentrations were 3.5–5.7, thereby implying that indoor sources are more important contributors to the indoor levels than outdoor sources. In Thailand, the monitoring of VOCs of ambient origin has been drawn substantially greater attention than that of indoor VOCs due to their outdoor large emissions from industry and vehicles. The Pollution Control Department of Thailand (PCD) has prioritized and set the national standard of 9 VOCs in the ambient air based on their toxicity and exposure assessments. These include benzene, vinyl chloride, 1,2-dichloroethane, trichloroethylene, dichloromethane,

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