Building and Environment 46 (2011) 2230–2237

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

Modeling ventilation rates in bedrooms based on building characteristics and occupant behavior

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ARTICLE INFO

Article history:
Received 21 December 2010
Received in revised form
2 May 2011
Accepted 5 May 2011

Keywords:
Ventilation rate
Building characteristics
Occupant behavior
Carbon dioxide
Homes
Linear regression model

ABSTRACT

Air change rate (ACR) data obtained from the bedrooms of 500 Danish children and presented in an earlier paper were analyzed in more detail. Questionnaires distributed to the families, home inspections and interviews with the parents provided information about a broad range of residential characteristics and occupant behavior. These were tested in several linear regression models to identify the degree of effect each selected independent variable has on the total ACR. The measured ACRs are summarized by some of the most significant variables such as room volume (higher ACR in smaller rooms), number of people sleeping in the bedroom (higher ACR with more people), average window and door opening habits (higher ACR with more opening), sharing the bedroom with other family members (higher ACR in shared rooms), location of the measured room (higher ACR above ground floor), year of construction (lowest ACR in buildings from early 1970s), observed condensation on the bedroom window (higher ACR at less condensation), etc. The best-fitting model explained 46% of the variability in the air change rates. Variables related to occupant behavior were stronger predictors of ventilation rate (model $R^2 = 0.30$) than those related to building characteristics (model $R^2 = 0.09$). Although not perfectly accurate on a room-to-room basis, our best-fitting model may be useful when a rough estimate of the average air change rate for larger study populations is required in future indoor air quality models.

1. Introduction

The concentration of a pollutant in a space is a balance between sources and sinks. Information about indoor sources can, to some degree, be estimated from data obtained from questionnaires or from interviews. In many cases ventilation is a major sink and thus a key parameter in an attempt to predict concentrations of pollutants for the purpose of assessing exposure or health effects in a space. Numerous previous studies reported air change rates in connection with the presence of dampness indicators, mite allergens, radon or occupant comfort and health [1–9]. However, measurements of ventilation rates can be time-consuming and costly. Therefore, in many epidemiological studies of indoor air, such measurements are not performed. In such studies, estimation of ventilation rate from information obtained from questionnaires or from interviews would be desirable. This is not an easy task, as the ventilation rate in a building can be affected by many different factors related to the building, the occupants and the outside weather conditions.

The present paper explores the possibilities of predicting the ventilation rate in homes. Earlier studies were limited to simply reporting air change rates in a number of residences and comparing them by a limited number of parameters, such as house type, age of the building or type of ventilation in the home [10–12]. More recent studies tried to find a link between ventilation rate in residential buildings and, for instance, season, geographic location or outdoor temperature and wind conditions [13–15]. Several previous works focused on the impact of occupant behavior on the ventilation of spaces and indicated a strong influence of behavior on the air change rates in buildings [15–21].

Several models predicting residential natural ventilation and infiltration exist [22,23]. A recent study compared ventilation rates predicted by three models based on questionnaires and meteorology to air change rates measurements across 31 detached homes in central North Carolina [24]. For the individual model-predicted and measured air change rates, the median absolute difference was up to 50%. Results separated by season, window status (closed vs. open) and weather condition (stack dominated vs. wind dominated) indicated that while the models tend to underestimate the actual ventilation rate under most conditions, some models may significantly overestimate it under some of the conditions. The prediction of ventilation rate may often be difficult as the required

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doi:10.1016/j.buildenv.2011.05.002