Estimation of carbon monoxide levels in a room during smoldering, flaming growth and ventilation-limited stages of residential fires

Katsuya Suenobu (K110609)

Keywords: carbon monoxide, residential fire, compartment fire, smoldering, zone model

Building fires killed 10,477 people excluding arson and suicidal fires in Japan in the ten year period 1991 to 2000. Residential fire deaths account for 87% of those building fire deaths. This paper focused on the fire deaths caused by carbon monoxide poisoning/asphyxiation, which occurs commonly in a very early smoldering stage of fire, and in contrast, in a developed post-flashover stage of fire.

An analysis of Japan's statistical fire data revealed that the causes of death in fire are closely related with the relative position of victims to the fire origin. In a small scale fire in which damaged floor area is less than 1 m^2, one of the general patterns of death is caused by cigarettes as ignition source igniting such as futon/cushion, paper/trash/garbage, (tatami) floor, and (carpeting) textiles. The cause of death is commonly attributed to carbon monoxide poisoning/asphyxiation. Another common scenario in residential fire deaths is of the people who were in a place remote from the fire origin. In this case, although the damaged area by fire is generally large, the cause of death is attributed by 60 % to carbon monoxide poisoning. These two scenarios can be considered as typical in fire deaths caused by smoke inhalation, or carbon monoxide poisoning.

In order to verify the actual hazards of carbon monoxide in smoldering fires, flaming growth and then ventilation-limited fires, a survey of literature have been done. According to the survey results, it was found that prediction of carbon monoxide may be possible by zone models using empirical correlations for carbon monoxide. For the smoldering fire, direct measurement of (smoldering) burning rate and carbon monoxide yield may be applied as input data for a zone model. It was also learned that empirical Global Equivalence Ratio models may also be applied to flaming growth and ventilation-limited stages of fire, in order to predict the carbon monoxide levels.

Typical conditions were set respectively for a smoldering-futon fire and a growing flash-over fire in a common seized Japanese residential room. Calculations were conducted for obtaining carbon monoxide levels as well as carbon-monoxide doses of human body for both cases. The calculation results showed that in the smoldering fire, carbon monoxide-hemoglobin (CO-Hb) concentration of 30 % in the blood may be reached about one hour inhalation of room air where smoldering combustion of futon is continuing. This concentraton of CO-Hb may affect people's ability to move for escape. As for the flash-over fire, it was found that the carbon monoxide concentration of several % is attained immediately after the flash-over, which may contaminate seriously the escape route for the person in the remote place almost instantly.