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MODELLING OF PARTICULATE MATTER INFILTRATION IN THE BAROQUE LIBRARY HALL IN PRAGUE

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Indoor air quality assessment in museums and libraries is important as indoor pollutants threat the preservation of the collections. Particulate matter (PM) can cause damage of the materials by particle soiling or chemical reaction due to deposition and absorption. Indoor pollutants either originate from indoor sources or penetrate indoors through the building envelope.
The aim of the current work was to analyze the characteristics of indoor PM and the influence of outdoor PM to the indoor PM levels in the Baroque Library Hall in Prague (Czech Republic).
Three intensive campaigns took place during spring, summer and winter 2009. The number concentration of PM was measured both indoors and outdoors with an APS (TSI, 0.5 – 20 μm) and an SMPS (TSI, 14 – 700 nm) instruments. The indoor particle number concentration was modelled using a dynamic mass balance model:

$$\frac{dC_{in}}{dt} = PaC_{out} - aC_{in} - kC_{in} + \frac{S}{V}, \quad (1) \qquad \frac{dC_{in}}{dt} = PaC_{out} - aC_{in} - kC_{in} \quad (2)$$

where, C_{in} is the indoor particle concentration, C_{out} is the outdoor particle concentration, t is the time, V is volume of the area under study, P is the penetration efficiency, a is the air exchange rate, k is the deposition rate and S is the emission rate of particles. Under the absence of primary sources (equation 2), the independent parameters are k and P.
In order to reveal the influence of outdoor PM to the indoor concentration, equation (2) was evaluated for different pairs of k and P. The results revealed a linear relationship between the two parameters with no unique solution. Table 1 presents the best-fitted values of k and P for each measurement period. Moreover, a dependence of k and P on particle size found when the model applied on the different size fractions. Higher rates of k found on nucleation (< 100 nm) and coarse (> 2.5 μm) particle modes and higher penetration efficiency on accumulation (100 nm $< d < 710$ nm) and fine ($d < 2.5$ μm) particle modes. High correlation between the measured data and the modeled values found in most cases with average $R^2 = 0.9$, indicating that the indoor concentration is well described by equation (2). Nonetheless, in the coarse particle mode, the correlation was low and R^2 varied between 0.1 – 0.58, mostly due to inability of the model to compute the several peaks of indoor number concentration.

Table 1. Input parameters of the modeled indoor concentration.

	APS			SMPS		
Input parameter	Spring	Summer	Winter	Spring	Summer	Winter
Penetration efficiency (P)	0.45	0.35	0.62	0.51	0.34	0.55
Deposition rate (k), min^{-1}	0.0008	0.0001	0.0012	0.00026	0.00011	0.00041
Air exchange rate (a), min^{-1}	0.0022	0.001	0.0025	0.0022	0.001	0.0025

Fine particles found to dominate both the indoor and outdoor number concentration with fractions close to 0.99 and 0.98 respectively. Along with higher I/O ratio (~ 0.6) on 0.1 – 1 μm particle sizes, it is believed that the enrichment of fine particles inside the library is the result of particle penetration from outdoors. The relationship between indoor and outdoor pollutants at the same site is also reported in [1]. On the other hand, low response of the model at the coarse particle mode, especially at periods with increased PM number concentration (peaks) suggests the existence of indoor sources. It is believed, that during these periods, indoor sources correspond to human presence inside the library. Indeed, all the increased concentration periods reflect to visiting hours. Moreover, the coarse PM indoor number concentration during visiting hours (10 am – 17 pm) increased by 55 %, supporting the above assumption. In order to determine the indoor emissions, the equation (1) was used instead of equation (2). The average particle emissions inside the library calculated at 9.7×10^5 particles min^{-1}. In summary, fine particles likely originate from outdoors through the building envelope, whereas, coarse particles are generated or transported indoors by the visitors of the library.

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[1] López-Aparicio, S., Smolík, J., Mašková, L., Součková, M., Grøntoft, T., Ondráčková, L., Stankiewicz, J., (2011). Relationship of indoor and outdoor air pollutants in a naturally ventilated historical building envelope. *Building and environment*, 46, 1460-1468.