



## Relationship of indoor and outdoor air pollutants in a naturally ventilated historical building envelope

S. López-Aparicio<sup>a,\*</sup>, J. Smolík<sup>b</sup>, L. Mašková<sup>b,c</sup>, M. Součková<sup>d</sup>, T. Grøntoft<sup>a</sup>, L. Ondráčková<sup>b</sup>, J. Stankiewicz<sup>d</sup>

<sup>a</sup>Norwegian Institute for Air Research, Instituttveien 18, P.O. Box 100, NO-2027 Kjeller, Norway

<sup>b</sup>Laboratory of Aerosol Chemistry and Physics, Institute of Chemical Process Fundamentals AS CR, v.v.i., Rozvojová 135, 165 02 Prague 6, Czech Republic

<sup>c</sup>Charles University in Prague, Faculty of Science, Institute for Environmental Studies, Benátská 2, 12 801 Prague 2, Czech Republic

<sup>d</sup>National Library of the Czech Republic, Klementinum 19, 110 00 Prague 1, Czech Republic

### ARTICLE INFO

#### Article history:

Received 7 September 2010

Received in revised form

12 January 2011

Accepted 12 January 2011

#### Keywords:

Indoor/outdoor ratio

Natural ventilation

Ammonia

Library

Organic acids

### ABSTRACT

Concentrations of NO<sub>2</sub>, O<sub>3</sub>, SO<sub>2</sub>, acetic and formic acids, HNO<sub>3</sub> and NH<sub>3</sub> were measured inside and outside a historical building, the Baroque Library Hall (BLH) in the National Library in Prague (Czech Republic). The naturally ventilated system of the building, the restriction of personnel access, reduced groups of visitors and absence of activities which could influence indoor pollutant concentrations are characteristics that make the Baroque Library Hall a suitable location to study the influence of outdoor environment on the indoor air quality. The relationship between indoor and outdoor (I/O) concentration was investigated to assess the infiltration of outdoor generated pollutants. Outdoor and indoor pollution sources were determined and, infiltration of ammonium nitrate and a shift of the equilibrium to the gas phase were the reason for the high concentration of ammonia measured inside the BLH. A significant seasonal variation was observed and interpreted as a consequence of different infiltration regime associated with indoor–outdoor temperature differences, which in addition drives dilution processes of indoor generated pollutants. Based on the indoor air quality assessment performed in the BLH with regard to human and material exposure, there is reason for concern about material preservation and in particular paper at the BLH.

© 2011 Elsevier Ltd. All rights reserved.

### 1. Introduction

Indoor air pollution is an important topic in modern times. People in western countries spend approximately 90% of their time indoors, so exposure to indoor air has a major impact on the overall intake of potentially hazardous air pollutants. Air pollution affects the durability of materials [1] and has been associated with the induction or exacerbation of allergic conditions and asthma as well as with fatigue, headache, cough, and nasal, eye, throat or skin irritation [2,3]. Indoor pollutants constitute a wide variety emitted from both indoor and outdoor sources, whose concentration is in addition related to the building envelope and the activities therein. Models have been developed to address pollutant penetration across building envelope [4,5]. However, research is still needed to determine to which extent the building envelope relates to the indoor air quality. Oxidant compounds such as NO<sub>2</sub> and O<sub>3</sub> are widely known to have negative effects on health [6] and to degrade materials such as cultural heritage objects [7–9]. Exposure to acidic pollutants has

been suggested as a possible link to respiratory health problems [10] and studies on indoor volatile organic compounds (VOCs) are receiving an increasing interest in the scientific community [11–14]. Paper- or cellulosic-based materials from books and manuscripts release a wide variety of volatile organic compounds (VOCs), which are commonly found in high concentration in libraries and archives due to degradation processes [15]. Some of these pollutants have been found to cause damage such as a significant reduction in the degree of polymerisation of cellulose in paper [16], which indicates the complex relationship between the emission from the material and the degradation of the material by the emitted pollutant. From the point of view of human pollution exposure, the indoor air quality inside libraries and archives is a major concern for the personnel working there and for visitors.

Air pollutants in the indoor environment can be divided according to their sources into 1) those generated outdoors, which infiltrate into the indoor environment, and 2) those generated indoors. Abundant indoor inorganic contaminants are SO<sub>2</sub>, NO<sub>2</sub>, O<sub>3</sub>, nitric acids (HNO<sub>3</sub>), CO<sub>2</sub>, CO and nitrous acid (HNO<sub>2</sub>). Combustion processes are responsible for the generation of NO<sub>2</sub>, SO<sub>2</sub> and CO which, in the absence of indoor sources (e.g. tobacco smoke, woodstoves and fireplaces, gas

\* Corresponding author. Tel.: +47 63 89 80 74; fax: +47 63 89 80 50.  
E-mail address: [sla@nilu.no](mailto:sla@nilu.no) (S. López-Aparicio).