Indoor Air Quality Modelling for Tehran Museums by IMPACT

Shafiepour, M.[1], Ashrafi, Kh.[2], Tavakoli, A.[3]*

1- Assist. Prof., Graduate Faculty of Environment, University of Tehran shafiepour@ut.ac.ir

2- Assist. Prof., Graduate Faculty of Environment, University of Tehran khashrafi@ut.ac.ir

3-Ph.D. student, Faculty of Environment, University of Tehran

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Introduction

Indoor air quality (IAQ) generally refers to the quality of physical, chemical and biological characteristics of air in an indoor environment. Indoor air pollution could threat people's health and on the other hand has long been recognised as a significant agent of deterioration of cultural heritage collections housed in museums, galleries, archives and library buildings. The most important gases that are sourced outdoor have long been considered to be Sulphur Dioxide (SO_2), Nitrogen Dioxide (NO_2) and Ozone (O_3). Considering valuable objects kept in museums and cultural heritage buildings, and the importance of maintaining them, it is necessary to use a method with the ability to estimate the concentration of indoor pollutants and evaluate their effects on collections. In this research, attempts have been focused to survey the concentration of pollutants in two important museums in Iran, and consequently the data produced by mathematical models are compared with real measured data. IMPACT[1] model has been developed as a software tool for estimating the damaging levels of air pollutants concentrations inside cultural heritage buildings.

Museums Studied

Pardisan Biodiversity Museum is placed in Pardisan Park with an area of 1,317 m^2. The museum is confined between four crowded highways located in Tehran- Iran which causes a large amount of pollutants emitted from automobile exhausts that can enter to the museum and damage the valuable exhibited items.

Persian Carpet Museum of Iran is located on the north side of the Laleh Park, with two heavily congested streets passing along the eastern and western sides of the park. Persian Carpet Museum with a total area of 3,400 m^2 has been used for exhibiting rugs, carpets and carpet pictures and includes a unique part of Persian culture, the most inestimable carpets from the 9th century to date.

Adopted Approach

Measurement method

Determining concentrations of two important pollutants namely NO_2 and SO_2 were the focus point of this research. Sampling was performed in March 2008, during the peak traffic volumes in the adjacent highways and streets. Sampling was performed by means of tedlar bags. Sampling indoor air quality was performed to compare the real concentration of pollutants obtained from measurements with the results produced later by mathematical models. Table 1 shows the average amounts of measured data.

Table 1: The average concentration of pollutants in Pardisan Museum (left) and Persian Carpet Museum (right)

Average	SO_2 (ppb)	NO_2 (ppb)		SO_2 (ppb)	NO_2 (ppb)
Outdoors	6.764	24.52		5.89	23.49
Indoors	6.25	25.201		6.03	27.81

Corresponding author: Tel: 09132076023 E-mail: atavakkoli@ut.ac.ir

Material and Methods

After measurement of pollutants' concentration, a mathematical model was used to evaluate the indoor concentrations in order to predict future circumstances. IMPACT model was selected for this purpose. Considered special pollutants consist of sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and ozone (O_3). IMPACT is a single zone model, so it is necessary to pay attention to links and relations between zones. This model relates the indoor/ outdoor pollutant ratio (C_i/C_o) directly to building parameters and assumes the zone to be modelled, which could be a whole building, room or gallery or display case, as a single and well-mixed zone. A very salient and innovative feature of this model is accounting materials and coverings that are used indoor. This parameter can be used for evaluating how well a particular pollutant gas will react and deposit on a particular surface material. With this explanation, IMPACT inputs consist of pollutant concentrations, indoor and outdoor temperature, relative humidity, wind speed, interior volume and surface covering materials used indoor.

Discussion of Results

After measuring outdoor pollutants' concentrations and determining surface areas of covering materials, the model was used to predict concentration of indoor pollutants.

Modeling results for Pardisan Biodiversity Museum

IMPACT model outputs, measured data and their comparison for different pollutants of NO_2, SO_2 and O_3 are shown in Table 2. By observing the results of Impact model, the effective role of some materials in adsorption and reduction in air pollution values can be understood. This note can be used to improve indoor air quality, for example by increasing the ineffective surfaces in pollutant adsorption and making a better decision for design before construction.

Table 2: Comparison between IMPACT results with measured data in Pardisan Museum (left) and Persian Carpet Museum (right)

Results	SO_2 (ppb)	NO_2(ppb)		SO_2 (ppb)	NO_2(ppb)
Modeled	5.28	23.78		4.95	21.38
Measured	6.25	25.201		6.03	27.81
Accuracy level	84 %	94 %		82 %	77 %

In order to improve indoor air quality and reduce pollutant concentrations, different techniques should be surveyed. For example by reducing air change rate from 3 to 1.5 viz-a-viz air tightness in Pardisan Museum, and keeping other parameters constant, air pollutant concentration will decrease. Another option offered is using a ventilation system equipped with a filter which has different efficiencies of for example 60% or 80%, recirculating 80% of indoor air, and air intake is equal with air change rate per hour (ach). Tables 3 and 4 show the obtained results.

Table 3: Comparison of IMPACT results with offered methods in Pardisan Museum

Results	NO_2(ppb)	SO_2 (ppb)	O_3 (%)
Modeled	23.78	5.28	78
Decrease ach to 1.5	23.05	4.60	69
Using ventilation & filter (60%)	16.43	3.92	58
Using ventilation & filter (80%)	14.71	3.52	52
Integrating both methods (ach + filter 60 %)	16.18	3.45	51
Integrating both methods (ach + filter 80 %)	14.47	3.11	46

Modeling results for Persian Museum

For Persian Carpet Museum, methods used for Pardisan Museum as described in 4.1 were repeated. Model results show the important role of cloth, painting, sandstone and calcareous in reduction of air pollutants concentration.

Some suggestions may improve indoor air quality and reduce air pollutant levels in Persian Carpet Museum. For example decreasing air change rate from 2 to 1 by reduction in air pollutants concentration is achievable, by making some changes in the entrance of the museum, using a ventilation system, similar in characteristics to the one suggested for Pardisan Museum, or integrating both methods.

Table 4: Comparison of IMPACT results with offered methods in Persian Carpet Museum

Results	NO_2(ppb)	SO_2 (ppb)	O_3 (%)
Modeled	21.38	4.95	90
Decrease ach to 1.0	19.70	4.50	84
Using ventilation & filter (60%)	17.85	4.18	75
Using ventilation & filter (80%)	16.91	4.01	71
Integrating of both methods (ach + filter 60 %)	16.68	3.83	71
Integrating of both methods (ach + filter 80 %)	15.97	3.65	67

It is obvious that suggestions such as reduction in air change rates, using mechanical systems equipped with filter and synthetic methods have an effective role on the improvement of indoor air quality.

Conclusions

The most important result of this paper is showing the compatibility between modeled results to real measured data. This value is in the range of 84%- 94% for Pardisan Biodiversity Museum and 77% - 82% for Persian Carpet Museum. Since the concentrations of the indoor pollutants in Persian Carpet Museum are more than the outdoor air due to the equality of the maximum predictable level of pollutants from IMPACT model to the outdoor concentration, a reduction in accuracy of model is expected. Hence, the hypothesis of no indoor sources is valid with this explanation. For Pardisan Biodiversity Museum the indoor pollutants level are similar to the outdoor ones and these effects would be related to superabundant rate of air change. The effects of different suggestions for improving indoor air quality are demonstrated. These suggestions use mechanical systems, an effective filter, and reduction in air change rate or integrating the two. A useful application of this model is determining the role of different covering surfaces in adsorption of pollutants. This point can be considered as an inexpensive way for air quality improvements. Selection of suitable covering surfaces in the building before construction can influence the adsorption of gaseous pollutants and improve indoor circumstances indirectly. Using this methodology, that adopts such modeling activities as a regular procedure, may be appropriate for improving living standards and indoor air quality in order to protect our valuable items in museums even before using ventilation systems which cause a waste of energy and irreparable damage to our natural or human heritages.

Key words

Air Pollution, Indoor, Modeling, IMPACT, Museum.