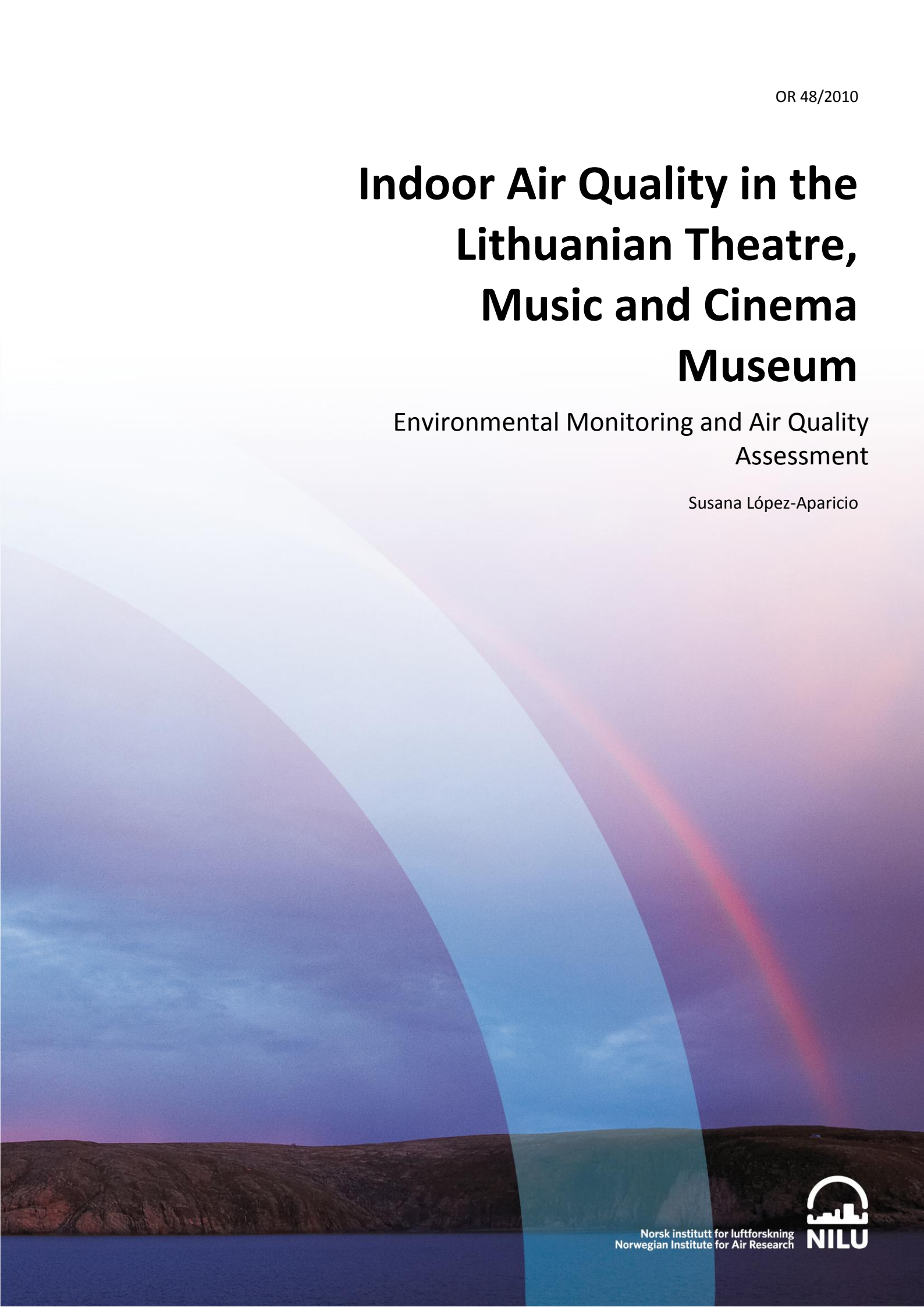
OR 48/2010

Indoor Air Quality in the Lithuanian Theatre, Music and Cinema Museum

Environmental Monitoring and Air Quality Assessment

Susana López-Aparicio



Norsk institutt for luftforskning
Norwegian Institute for Air Research
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Summary

This report synthesizes the results obtained by the Norwegian Institute for Air Research (NILU) within the project "Environmental monitoring and air quality assessment in the Lithuanian Theatre, Music and Cinema Museum" in Vilnius (Lithuania).

The project was carried out by the Lithuanian Theatre, Music and Cinema Museum (LTMCM) and the Norwegian Institute for Air Research as partners, with assistant of the Republic of Lithuania, and financing from the Norwegian Financial Mechanism (EEA Norway Grants) under the block grant: "Transfer of Experience and Strengthening of Cooperation among Local, Regional and Euroregional Partners in Lithuania and Norway".

The main goal of the project is to perform a characterization of the indoor air pollution in the Lithuanian Theatre, Music and Cinema Museum. The report describes the methodology used in the project, which constituted the main transfer of experience from the Norwegian to the Lithuanian partner. The results and evaluation constitute the main block of the report and main achievements of the project. They provide the basis for the final conclusion and evaluation of the indoor air in the LTMCM concerning the preservation of cultural heritage objects.

Different conditions were observed in the LTMCM. The results obtained in storage rooms show low infiltration of outdoor generated pollutants such as NO_2 whereas higher infiltration is observed in the exhibition area. The highest infiltration was observed at street level. The results indicate that the building enveloped does not protect effectively against infiltration of outdoor pollutants such as NO_2 and particles. Indoor generated pollutants such as acetic acid were measured in very high concentration in one storage room with a significant source. This result indicates that the storage of materials sensitive to acetic acid in this room should be avoided.

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1 Introduction

Air pollution and its effects on cultural heritage objects have received an increased interest in the last decades. Air pollution constitutes a risk to materials and in particular to cultural heritage objects and artworks. Some of the documented adverse effects include the fading of paintings, blackening of surfaces, corrosion of metals, softening of details, decomposition and yellowing of paper, among other problems.

The valuable objects in the Lithuanian Theatre, Music and Cinema Museum constitute a wide representation of the modern Lithuanian history. However, degradation is observed on several objects both in exhibition and storage, which indicates that their preservation may be at risk. Degradation mechanisms can be symptomatic of an unacceptable environment with regard to climate parameters, such as temperature and relative humidity, or pollutant concentration. The museum, located in the Radvilai Palace, is situated in Vilnius' Old Town and exposed to intense traffic.

Indoor air pollutants can be divided according to their sources into two main groups, those generated outdoors and subsequently infiltrated indoors, and those generated indoors. Nitrogen dioxide (NO_2), ozone (O_3), sulphur dioxide (SO_2) and particulate matter are among the most important outdoor pollutants which enter the museum environment. The pollutants emitted indoors are mainly organic (e.g. volatile organic compounds, VOCs) and usually emitted from building materials. Several studies have been published about air pollution in museums and the degradation effects on cultural heritage objects (e.g. Thomson, 1986; Blades et al., 2000; Hatchfield, 2002; Tétreault, 2003).

1.1 Objectives

The main goal of the project is to perform a characterization of the indoor air pollution in the Lithuanian Theatre, Music and Cinema Museum (LTMCM). In order to achieve this goal, different locations in the storage area and exhibition rooms were selected for the measurements. Indoor air quality assessment, regarding the preservation of cultural heritage objects, is based on the results obtained by dosimetry (EWO dosimeter), measurements of single pollutant concentrations and particle deposition.

Specific objectives:

- Design of the measurement campaign to be performed in the Lithuanian Theatre, Music and Cinema museum.
- Measure the photo-oxidant effects of the environment by the Early Warning Dosimeter for Organic materials (EWO-dosimeter).

- Measurement of NO_2, as indicator of outdoor generated pollutants, by passive diffusion gas samplers.
- Measurement of organic acids (acetic and formic acids), as indicator of indoor generated pollutants, by passive diffusion gas samplers.
- Evaluation of particle deposition by glass slides.
- Evaluation of the results concerning the preservation of cultural heritage objects in the museum.

2 Methodology

2.1 Sampling location

The museum is located in the Radvilai Palace in the heart of Vilnius Old Town (Figure 1A and B). The historic palace housed the Public Theatre of Vilnius between 1795 and 1810, and at the second part of 19th century, it was used as houserooms, stores and pharmacy. The dimension of the museum is around 3 718 m^2, of which more than 1 500 m^2 are dedicated to exhibition area and approximately 500 m^2 to depository or storeroom.

The museum collection consists of a wide variety of valuable Lithuanian cultural heritage objects, reaching over 350 thousand exhibits which are placed mainly in store and, a small part of them, in exhibition. The main group of cultural heritage objects can be classified as paper objects, for instance programme sheets, posters, newsletters, photographs, and manuscripts among others. Other representative groups are composed mainly by wood objects, such as valuable rare music instruments from 18th – 20th century, and metal objects. The collection includes in addition films, vinyl, paintings, sound recording and textiles, such as costumes from personal collections of renowned Lithuanian actors and actresses, among others.

The building is located in the city centre of Vilnius. One of the two main facades faces a street with intense traffic (Figure 1B and Figure 1C) whereas the other is facing a backyard (Figure 1B and Figure 1D).

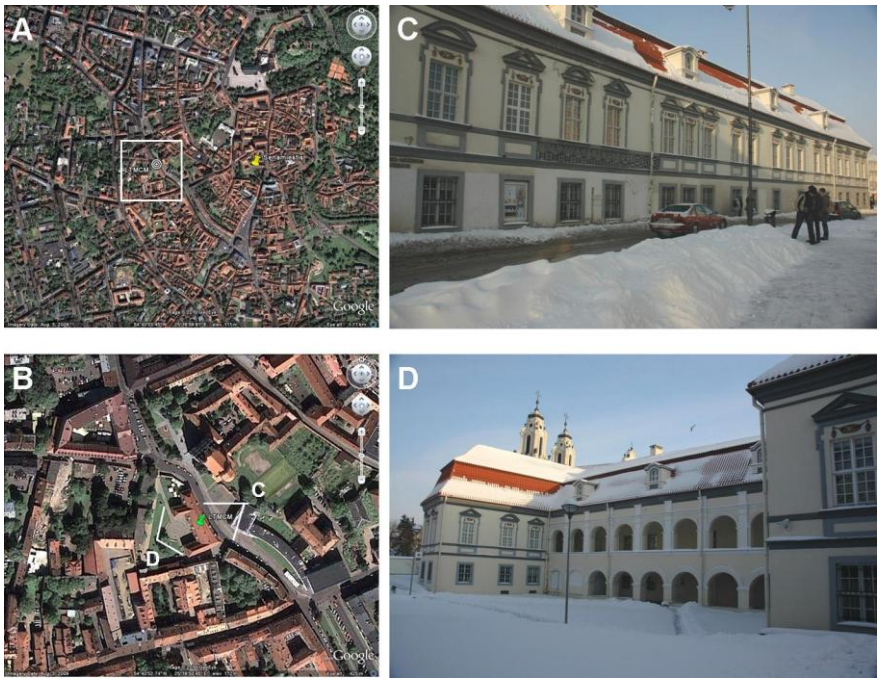

Figure 1: Location of the Lithuanian Theatre, Music and Cinema Museum (A and B) and main facades of the building, facing a street with intense traffic (C) and facing a backyard (D).

Five different sampling locations were selected inside the building in order to cover different environmental conditions. Figure 2 shows the five sampling locations and their position on the layout of the museum. Two of the sampling locations were in storage rooms (LM1 and LM2; Figure 2 and Table 1) whereas three sampling locations were in exhibition areas (LM3, 4 and 5; Figure 2 and Table 1). In addition, different physical characteristics such as presence or absence of window (Table 1) and whether the room is facing street or backyard were taken into account as criteria for the selection of sampling location.

Figure 2: Sampling locations selected for measurements and their locations on the layout of the museum.

Table 1: Description of the sampling locations selected in the project.

Ref	Floor	Room type	Material type	Description
LM1	2nd	Depository	Variety - mainly paper	Scenography depository, with window to the street
LM2	2nd	Depository	Variety - mainly wood	General depository, without window. Objects in storage are mainly musical instruments
LM3	1st	Exhibition	Mainly wood and metal pieces	Room facing the street side, collection of musical instruments
LM4	1st	Exhibition	Paper and paintings on the wall	Room of composers. It faces the backyard. Paper based objects exhibited inside showcases. Original paintings on the wall.
LM5	Ground	Exhibition	Textile, metal, paper	The room faces the street side at street level.

2.2 Environmental measurements

The photo-oxidant effects of the environment on organic materials were measured by dosimeter whereas pollutant (NO_2, acetic and formic acids) concentration measurement and particle deposition evaluation were performed by passive samplers as will be described in this chapter. Figure 3 shows the measurement stations used in the LTMCM.

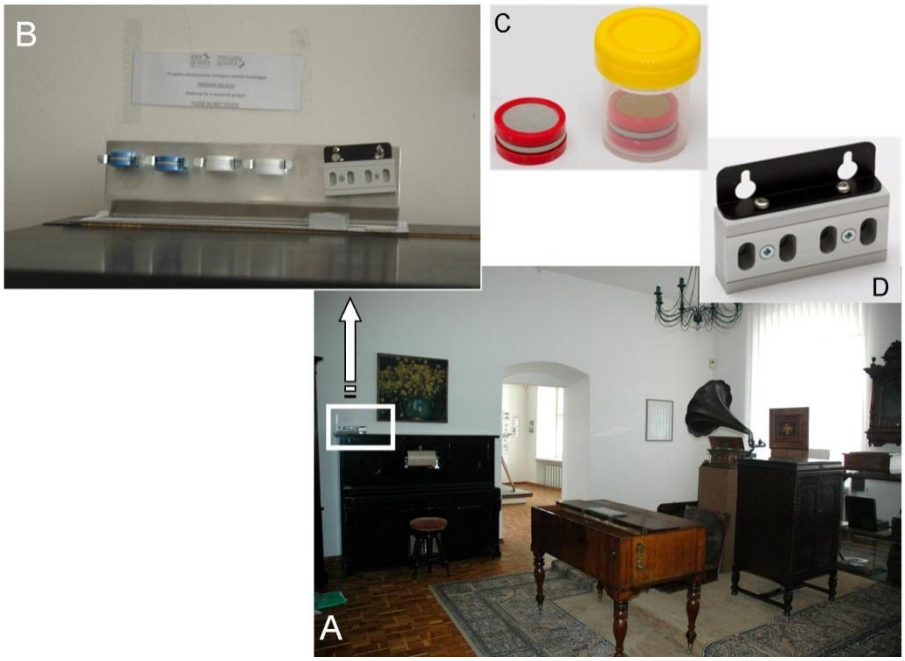

Figure 3: Dosimeter and passive diffusion samplers exposed in the LTMC Museum (A and B). C: Passive diffusion sampler from NILU. The colour indicates the gas (e.g. Red sampler: SO_2; Blue sampler: NO_2; White sampler: Organic acids). D: EWO dosimeter.

2.2.1 Dosimetry

The photo-oxidant effects of the environment were measured by the Early Warning dosimeter for Organic materials (EWO) developed by the Norwegian Institute for Air Research (NILU; Figure 3; Grøntoft et al., 2010).

The EWO dosimeter is a synthetic polymer sensitive to climate parameters (i.e. temperature, relative humidity and UV Light) and NO_2 and O_3, which are usually emitted outdoors and ventilated or infiltrate into the indoor environment. The environmental effect on the dosimeter polymer film is measured by photo-spectrometry as the change in UV absorption at 340 nm from before to after exposure. The relation between the EWO-response and the environment is based on a non linear dose response function found from the statistical analysis of the results obtained in a measurement campaign. Dose response functions for indoor locations outside (Equation 1) and inside enclosures (i.e. showcases; Equation 2) were defined (Grøntoft et al., 2010).

An evaluation of recommended response levels for the EWO as compared to effects on organic cultural heritage objects was performed based on existing knowledge in conservation science about the effects of the single environmental parameters on the heritage objects. The results from measurements with the dosimeter are reported as values of increasing environmental impact ranging from one to five. The evaluation of the indoor air quality is performed for five different locations with different degree of protection, from archive to external store with no control (Table 2).

Equation 1

Equation 2

Table 2: Location - Tolerability diagram for the EWO dosimeter results (Grøntoft et al., 2006).

Determined expectation	LEVELS				
	1	2	3	4	5
Archive / Store	Expected environment (acceptable)	Environment could be better	Environment is poor	Something is wrong with control	Serious problem with building or control
Purpose built museum	Environment is very good	Expected environment (acceptable)	Environment could be better	Environment is poor	Something is wrong with control
Historic Building	Excellent environment	Environment is very good	Expected environment (acceptable)	Environment could be better	Environment is poor
Open structure	Dosimeter is not responding	Excellent environment	Environment is very good	Expected environment (acceptable)	Environment could be better
External store with no control	Dosimeter is not responding	Dosimeter is not responding	Excellent environment	Environment is very good	Expected environment (acceptable)

2.2.2 Passive diffusion samplers

Organic acids (i.e. acetic and formic acid) and NO_2 concentrations were measured by passive diffusion gas samplers from the Norwegian Institute for Air Research (NILU; Figure 3). Organic acid samplers were analyzed by ion chromatography and samplers for NO_2 were analysed by photometry. The filter of the organic acids passive sampler is impregnated in an alkali, which is dissolved in an aqueous solution after exposure and the extracted acetate and formate are determined by ion chromatography. The mean concentration during the exposure time is estimated based on the quantity of extracted acetate and formate, a constant, which contains the diffusion constant for acetic and formic acids, and a factor based on the dimensions of the passive sampler. For NO_2, the filter of the passive sampler is impregnated in iodide (I^-) and the formed nitrite (NO_2^-) is determined by photometry. The NO_2 average concentration for the exposure time is estimated in the same way as for organic acids. The detection limit for NO_2 after one month of exposure is approximately 0.03 µg m^{-3} and for acetic acid and formic acid it is 0.5 µg m^{-3}.

2.2.3 Particle deposition

Glass slides were exposed during three months in the sampling locations selected in the LTMCM and particles were deposited by gravity. After exposure the glass slides were covered with GelLifter© and the deposited particles were collected and examined by microscopy. The GelLifters© were analyzed by optical microscopy using a Leitz Aristoplan microscope. Digital images where taken using a Leica DC Camera attached to the microscope and assisted by Leica IM Management system. The digital images (Figure 4A) are analyzed by the image processing software ImageJ. The image processing and the steps preceding the quantification of particles depend on the type of image. Previously to the quantification and characterization of particles, a homogeneous binary image (Figure 4B and Figure 4C) is needed, and might be achieved modifying brightness and contrast, by application of filters, adjustment of manual thresholds, and transformation to 8-bits image, etc.

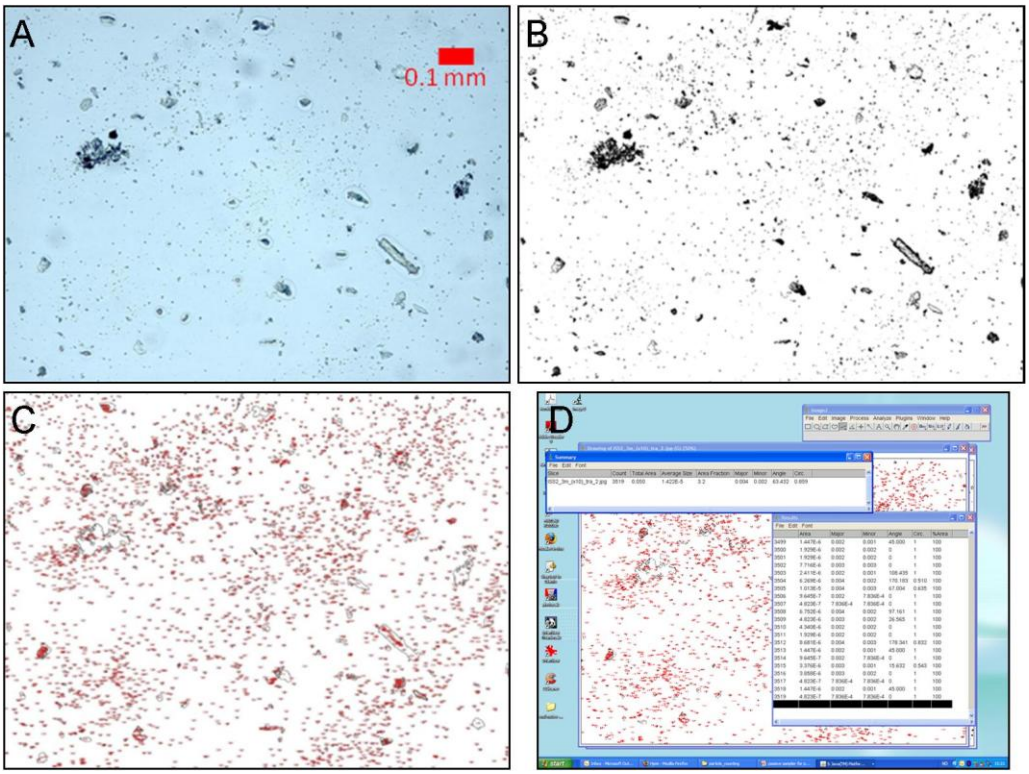

Figure 4: Procedure to quantify deposited particles on a glass slide by the processing of digital images.

2.2.4 Climate

Punctual temperature and relative humidity measures in the five sampling locations were performed daily by the personnel in the museum from February to May 2010, covering the exposure time of the EWO-dosimeters. Both temperature and relative humidity were measured with miniature hygrometers TFA with ± 1ºC and ± 5% RH accuracy (Figure 5). The information was registered in logs and at the end of the exposure time was provided to NILU for data analysis and evaluation.

Figure 5: Combined thermometer and hygrometer used for measuring temperature and relative humidity values.

3 Results

The results obtained within the project by the Norwegian Institute for Air Research are summarized on a database included in the Appendix of this report.

3.1 Dosimetry

Figure 6 shows the results obtained with the EWO dosimeter. Three out of five locations are classified as level 1, which means that the environment is acceptable for an "Archive Store" concerning photo-oxidant effects on organic materials. These locations are a depository rooms (LM1 and LM2; Table 1) and a gallery room (LM3; Table 1) which faces the street side of the building. The response of the EWO dosimeter in one of the storage room is cero (LM2; Figure 6). This room is a depository room without windows and therefore low infiltration of outdoor generated pollutants and low levels of light. Two out of the five sampling locations showed acceptable environment for a "Purposed Built Museum" (Level 2; Figure 6) very close to acceptable for a "Historic House" (i.e. Level 3). Both locations are used as exhibition areas, one facing the backyard (LM4) and the other facing the street (LM5).

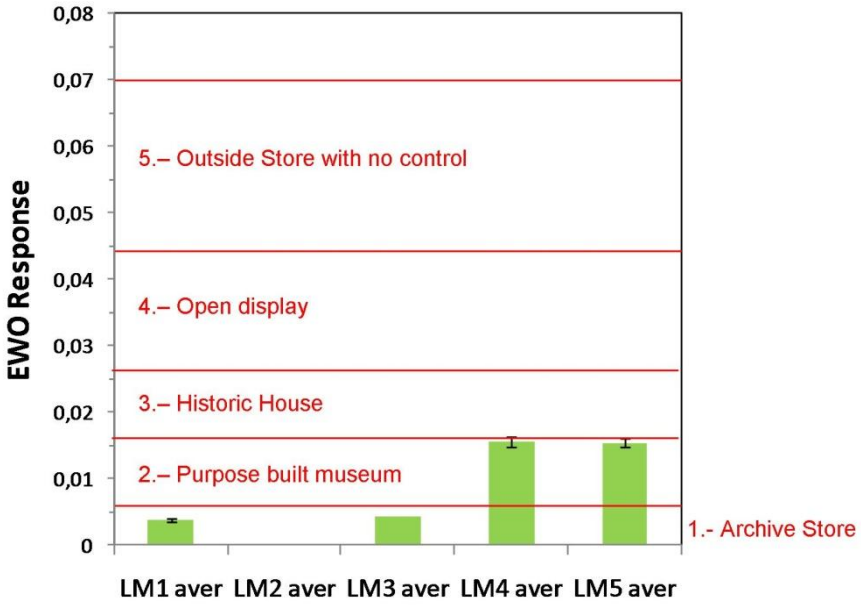

Figure 6: EWO dosimeter responses obtained in the five indoor locations in the LTMCM.

3.2 Pollutant concentration

Figure 7 shows the one month average concentration of NO_2 obtained inside the Lithuanian Theatre, Music and Cinema Museum. The concentration of NO_2 varies from 1 µg m^{-3} to approximately 30 µg m^{-3}. NO_2 is an outdoor generated pollutant which is infiltrated into the indoor environment. The lowest concentrations were measured in the depository or storerooms (LM1 and LM2; Figure 7) located on the top floor of the museum. The measurements performed in the exhibition areas show values above 10 µg m^{-3}, and the highest level in the room located at the ground floor and facing the street side of the building (LM5; Figure 7).

Two measurements were performed at the same floor and in room locations which face the backyard and the street (LM3 and LM4; Figure 2). The results show similar concentration of NO_2 and therefore both locations are exposed similarly to outdoor generated pollutants.

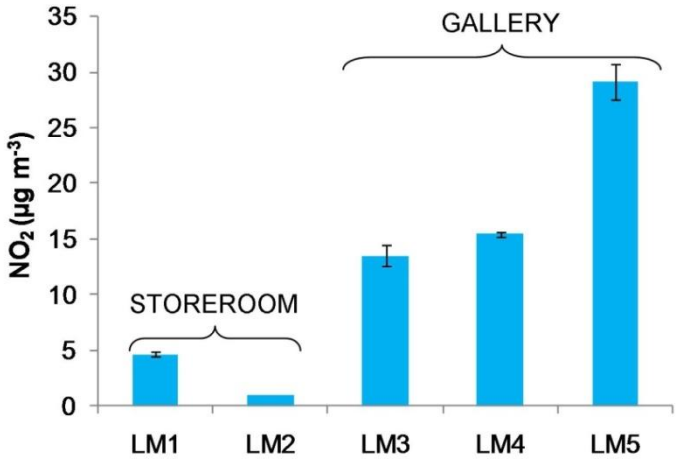

Figure 7: NO_2 concentration obtained in the Lithuanian Theatre, Music and Cinema Museum. Values represent the average from two parallel samplers. For abbreviation and locations characteristics see Table 1.

Organic acids are mainly emitted from materials such as wood, paint, varnishes among others, so they are mainly indoor generated pollutants. The concentration of acetic acid measured inside the LTMCM varies from 19 µg m^{-3} to approximately 280 µg m^{-3}. The lowest acetic acid concentration is measured in the indoor location which faces the street at ground level (i.e. LM5; Figure 8), whereas the highest concentration of acetic acid is measured in one of the depository or storeroom locations (i.e. LM1; Figure 8). Formic acid follows the same pattern as acetic acid (Figure 8).

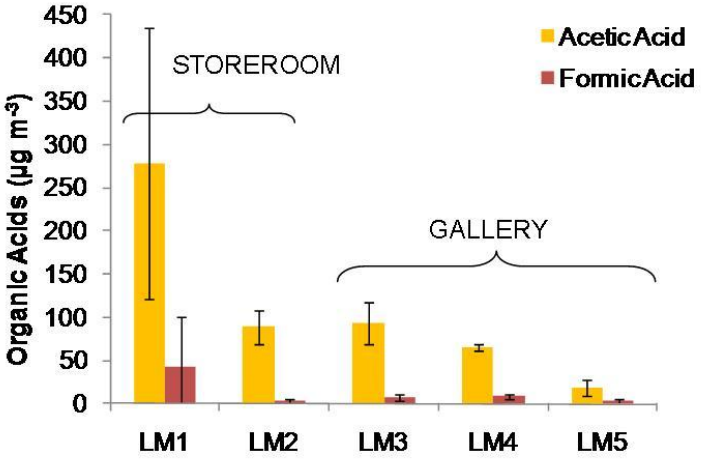

Figure 8: Organic acids (acetic and formic acids) concentration measured in the Lithuanian Theatre, Music and Cinema Museum. Values represent the average from two parallel samplers. For abbreviations and location characteristics see Table 1.

3.3 Particle deposition

Figure 9 and Figure 10 show the results obtained from the study of glass slides exposed in the five sampling locations exposed over three months. The results shown in Figure 9 represent average percentage of area covered with particles obtained from five digital images. The highest value was obtained in the location LM5, followed by LM1. The lowest value was obtained in the location LM2.

The particles deposited on the glass slides are mainly equidimensional and a low percentage of fibres were observed. In general, particles are mainly transported into the museum by visitors or they are infiltrated through the shield of the building (e.g. windows and doors). The high value obtained in the location LM5 might correspond to infiltration. The sampling station was placed on the interior window sill at approximately 3 meters from the visitor path.

The lowest obtained value (LM2; Figure 9) is in accordance with the characteristics of the room; restricted personnel access and lack of window. The depository room LM1 shows higher value than the exhibition areas LM3 and LM4. The room LM1 has window and infiltration through it may explain higher particle fraction. In addition, incense burning is a common practise in the nearby corridor to the LM1 location (personal communication) what may involve high emission of particles. However, the location LM2 shared the same corridor and the amount of particles is less significant (Figure 9 and 10).

The locations LM1, LM3 and LM5 have windows which face the traffic side of the building. The three locations show high percentage of area covered with particles (Figure 9 and Figure 10) and the results may indicate high infiltration from the street.

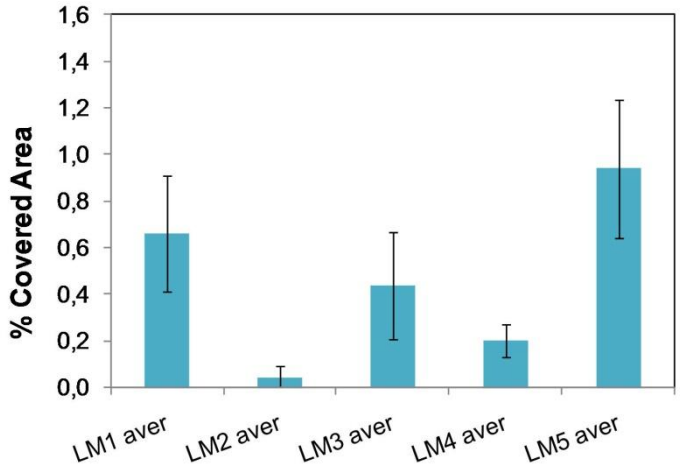

Figure 9: Average percentage of area covered with particles obtained in the five indoor locations in the LTMCM. For abbreviations see Table 1.

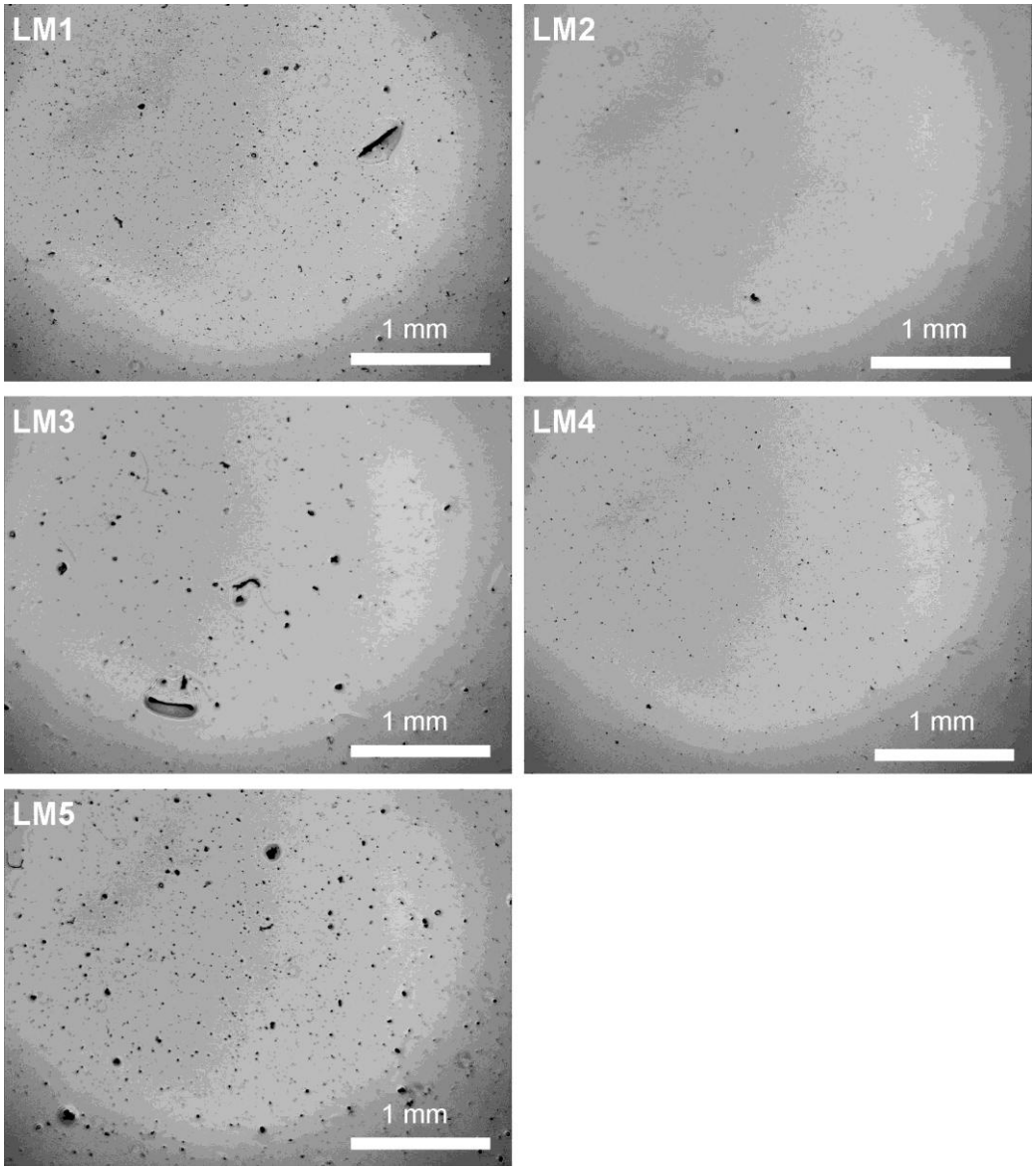

Figure 10: Digital images obtained from the glass slides exposed during three months in the LTMCM.

3.4 Climate

Figure 11 shows daily temperature and relative humidity measured in the five sampling locations. Temperature is low in every location and does not show significant variations. Relative humidity varies between 20-30% and 50-60% in all the locations except location LM1, in where relative humidity increases from approximately 40% to 50% from February to May 2010.

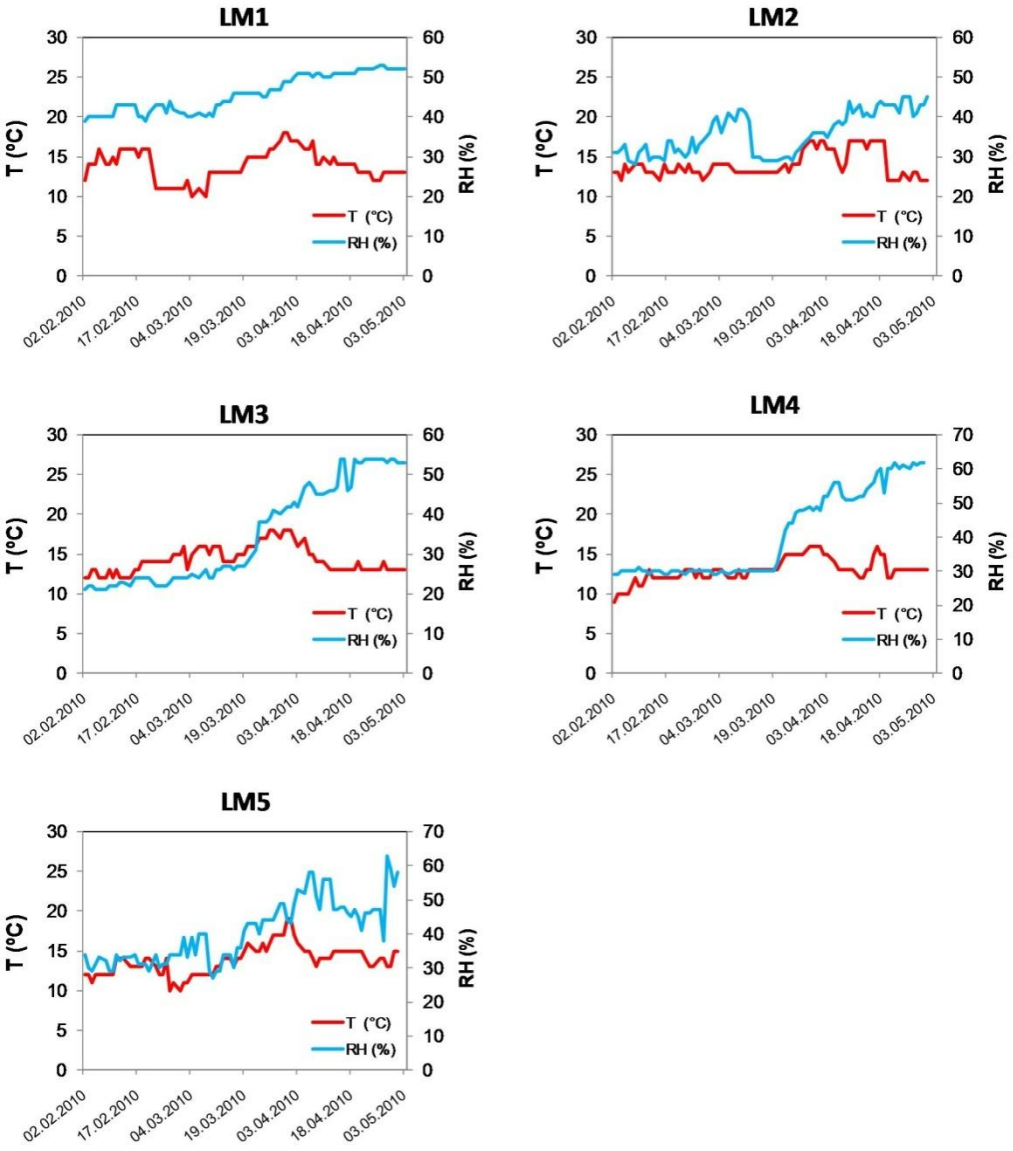

Figure 11: Daily temperature and relative humidity in the sampling locations. For description of sampling locations see Table 1.

4 Discussion and evaluation

Five different indoor locations were selected in the Lithuanian Theatre, Music and Cinema museum in order to evaluate the indoor air quality for the preservation of cultural heritage items. The locations were selected based on different criteria such as:

- Location in the museum, facing street or facing backyard;
- physical characteristic, presence or absence of window;
- type of materials (wood, metal, paper);
- type of room, storeroom or exhibition gallery.

4.1 Photo-oxidant effects

The photo-oxidant effects of the environment on organic materials were measured with the EWO dosimeter and the results indicate that the environment is acceptable for an archive / store (LM1, LM2 and LM3; Figure 6) or for a purpose built museum (LM4 and LM5; Figure 6). The locations LM1 and LM2 are storerooms, so the results are in conformity with the type of locations. The location LM3 is part of the exhibition gallery and faces the street side of the building on the first floor of a historic building, so the level 1 obtained by the EWO dosimeter (Figure 6) indicates that the gallery room LM3 has an excellent environment concerning photo-oxidant effects. Both LM4 and LM5 are gallery rooms of the historic building so level 2 obtained with the EWO dosimeter indicate that the environment is very good for the preservation of organic materials (Figure 6). The evaluation of the results obtained with the EWO dosimeter is summarized in Table 3.

Table 3: Photo-oxidant effects evaluation.

LOCATION	EWO evaluation
LM1	Acceptable
LM2	Acceptable
LM3	Excellent Environment
LM4	Very Good Environment
LM5	Very Good Environment

4.2 Outdoor generated pollutants

NO_2 was selected as indicator or outdoor generated pollutant which infiltrates or ventilates into the indoor museum. Nitrogen dioxide is well known as a highly reactive oxidant and corrosive compound. Some of the most documented effects are corrosion of copper, attack on calcareous stones and murals, and deterioration of pigments such as fading and colour change (see review López-Aparicio et al., 2009).

In order to evaluate the infiltration into the museum, different locations were selected from the building. The locations LM3 and LM4 were selected from the same floor facing the street and the backyard, respectively. The results obtained do not show differences between both rooms (Figure 7 and Figure 12) and therefore the location within the building concerning the distance to traffic

emissions is not a determinant parameter. The worst case scenario is observed in the room location LM5, where the concentration of NO_2 reaches 30 µg m^{-3} (Figure 12). The location LM5 is at the ground floor at approximately 2 metres from the traffic.

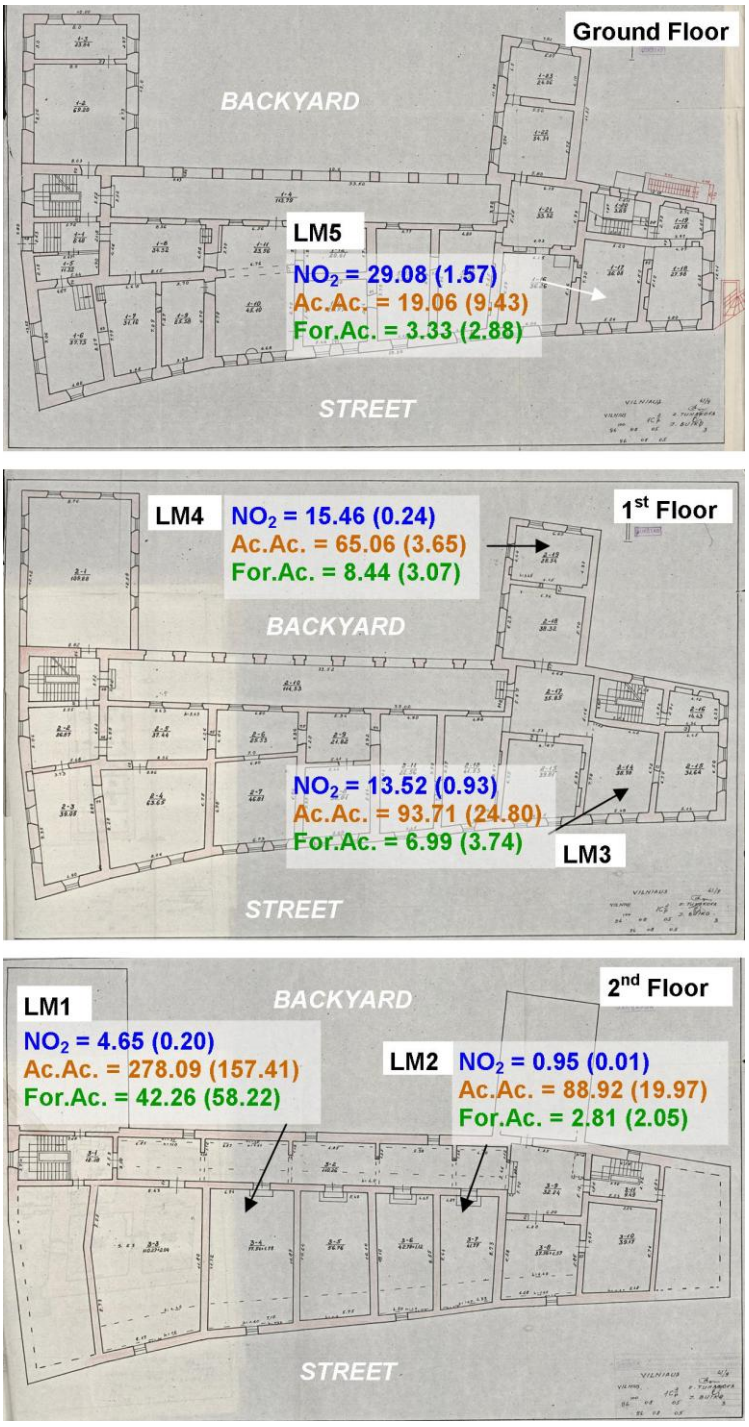

Figure 12: NO_2, acetic acid and formic acid concentrations in the LTMC museum. Values represent average from two parallel samplers. Numbers in brackets represent the standard deviation.

Outdoor NO_2 concentration in Vilnius during the NO_2 sampling period (February 2010) was available (Data from http://www.knowyourairforhealth.eu/). Hourly NO_2 concentration data from three different monitoring stations distributed across Vilnius (Figure 13) was collected and analysed. Average daily NO_2 concentration varies between 7 and 38 µg m^{-3} in the background and industrial stations (Figure 13), whereas daily average NO_2 concentration is between 17 and 62 µg m^{-3} in the traffic monitoring station (Figure 13).

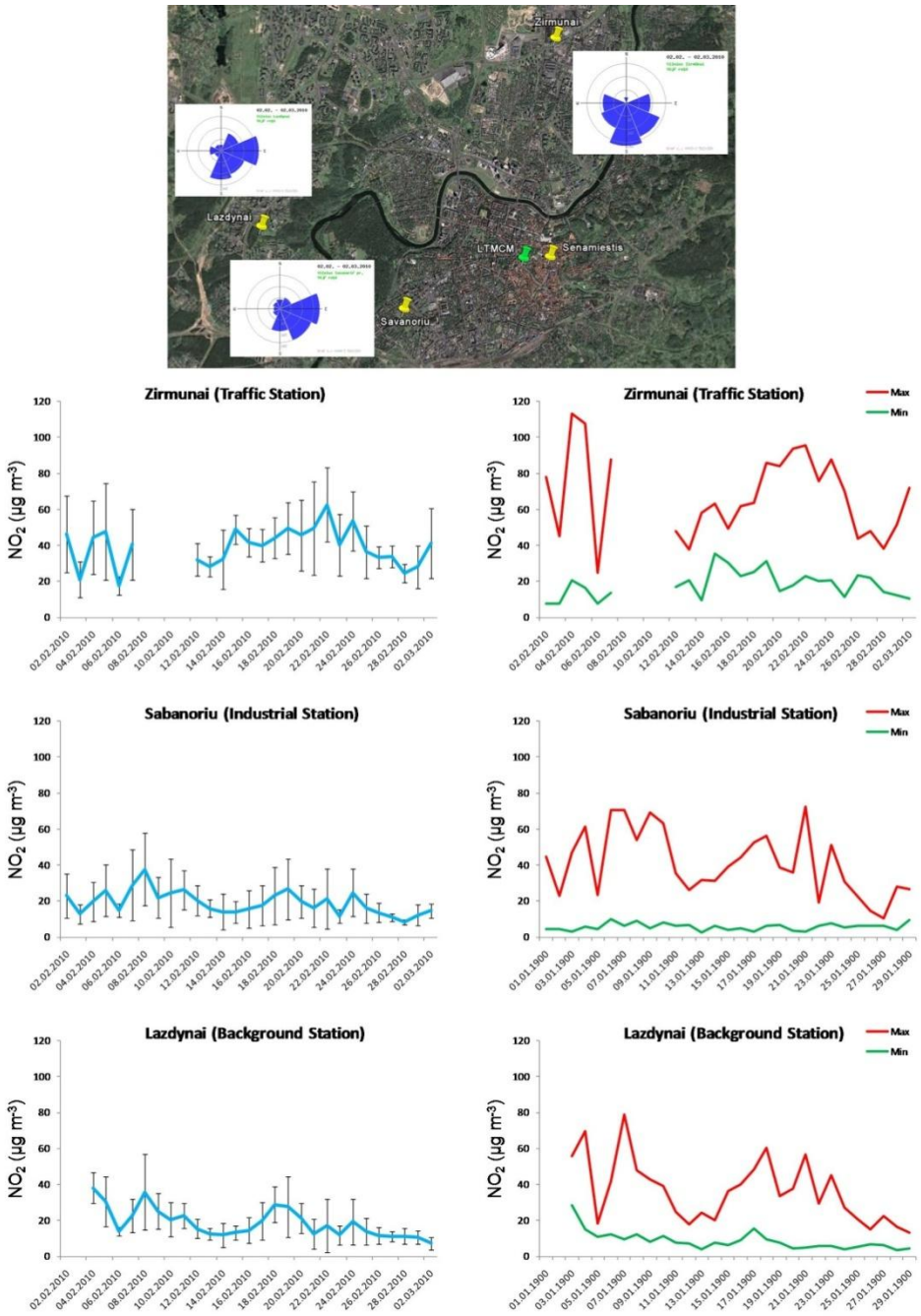

Figure 13 Location of monitoring stations and wind direction from February 2010 (top).Daily average (left) and maximum - minimum hourly value (right) of outdoor NO_2 concentration from monitoring stations in Lithuania. Data obtained from: http://www.knowyourairforhealth.eu/.

The traffic station was selected as representing of the outdoor air quality around the Lithuanian Theatre, Music and Cinema Museum. The month average concentration of NO_2 for the exposure time of interest is 39.27 µg m^{-3} (standard deviation: 10.67). Taking this value into account, we obtain an indoor / outdoor ratio (I/O) between 0.02 and 0.74 (Table 4). The lowest I/O ratio is observed in the two storage rooms, LM1 and LM2, indicating very low infiltration of NO_2, whereas the highest I/O ratio is obtained in the location LM5 illustrating that the building, and specifically the room LM5, does not protect efficiently against infiltration of outdoor pollutants.

Table 4: I/O ratio obtained in the different locations.

LOCATION	Indoor / Outdoor ratio (I/O)
LM1	0.12
LM2	0.02
LM3	0.34
LM4	0.39
LM5	0.74

Figure 14 shows a comparison between the results obtained by EWO dosimeter and passive gas samplers for NO_2 in different historical buildings. The photo-oxidant effects of the environment in the LTMCM are slightly lower than the effects measured in other institutions. However, the concentration of NO_2 is comparable. The location LM5 shows a concentration of NO_2 similar to that measured indoors in the Tower of London.

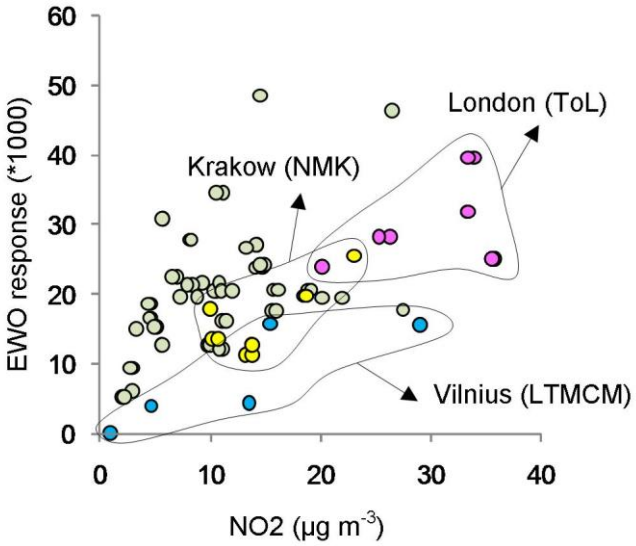

Figure 14 Comparison of the EWO responses and NO_2 concentration obtained in the LTMCM and in other Cultural heritage locations (Historic Buildings). As examples NMK (National Museum in Krakow) and ToL (Tower of London) are marked.

4.3 Indoor generated pollutants

Organic acids (acetic and formic acids) were selected as indicator of indoor generated pollutants. The formation of salt efflorescence with acetate on carbonate materials is a common phenomenon on artefacts such as shells, terracotta pottery or limestone objects. In addition, effect on metals and stone, embrittlement of paper, fading and degradation of pigments due to exposure to acetic acid have been observed (see review López-Aparicio et al., 2009).

Figure 12 shows the concentration of acetic and formic acids obtained in the five sampling locations. The highest concentration was obtained in the location room LM1, whereas the lowest concentration was obtained in the location LM5. Organic acids are emitted mainly from wood materials apart from paintings, lacquers, varnishes, among other sources. The location LM1 is a depository room with a large number of wooden drawers from which high emission of organic compounds may occur. The location LM5 is the only one with stone floor, while the others have wooden floors. This characteristic may explain the low concentration of organic acids obtained in the location LM5.

Concerning the preservation of cultural heritage objects, the location LM1 is the main concern due to the high concentration of organic acids detected (i.e. ≈280 µg m^{-3} of acetic acid and ≈ 40 µg m^{-3} formic acid). Acetic acid reduces the degree of polymerization of cellulose in paper and the location LM1 mainly holds paper based materials which may be under risk. According to the ISO 11799 (2003) concerning the requirements for archive and library material, the recommended levels of acetic acids are lower than 10 µg m^{-3}. However, normal indoor concentration levels vary between 40 – 100 µg m^{-3} (Figure 15 and Tétreault, 2003). A comparison with results obtained in other indoor locations is shown in Figure 15.

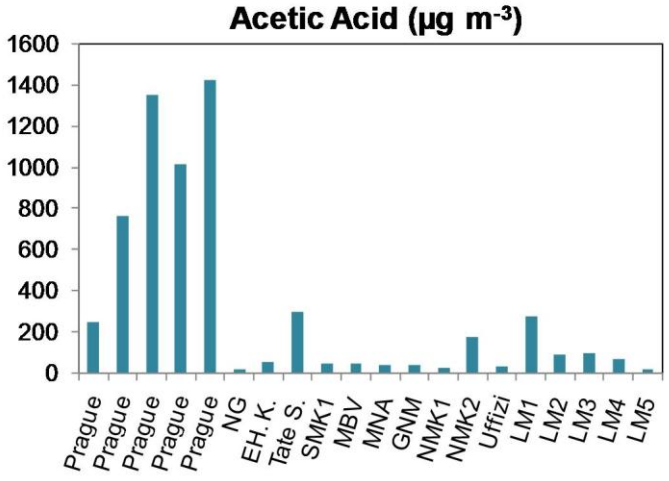

Figure 15: Comparison of the concentration of acetic acid obtained in the LTMCM (LM1, LM2, LM3, LM4 and LM5) and the concentrations obtained from other indoor studies. Data Source: NG (Oslo), EH.K (London), Tate (London), SMK1 (Copenhagen), MBV (Valencia), MNA (Mexico), GNM (Nürnberg), NMK1 (Krakow), NMK2 (Krakow) and Uffizi (Florence) from López-Aparicio et al., 2010a. Prague from López-Aparicio et al., 2010b.

4.4 Particle deposition

The highest percentages of area covered with particles were obtained in the three locations with windows facing the street (LM1, LM3 and LM5; Figure 9 and Figure 10). In addition the morphology of the particles is mainly equidimensional and low percentage of fibres brought by visitors was observed. These results indicate that particles are most probably infiltrated into the building envelope through windows and doors. Thus the building does not protect effectively against the infiltration of particles.

Particles constitute a risk for cultural heritage objects in museums as they cause soiling, are abrasive, provide sites for surface reactions and have a potential to damage artefacts due to their hygroscopic nature.

4.5 Climate

Relative humidity represents an essential environmental factor for diagnosis and risk assessment for cultural heritage objects. Relative humidity is defined as the ratio of the partial pressure of water vapour to the saturated vapour pressure of water at given temperature. It represents the amount of water vapour in the air as percentage at any given time.

Several materials (e.g. wood, paper, parchment, leather, bone, paintings, plaster or clay mineral based stones) are very sensitive to their water content which is in equilibrium with the relative humidity in the air. Changes in the moisture content influence changes of the physical state of the materials. For instance, when moisture is removed from some materials such as wood or bone they contract favouring distortion or cracking. Other materials such as paper, parchment, leather and natural textiles become less flexible and therefore more fragile.

Table 5: Average temperature and relative humidity (3 months), Max and Min. Numbers in brackets are standard deviations.

	T (°C)				RH (%)			
	Aver		Max	Min	Aver		Max	Min
LM1	13,9	(1,9)	18	10	46,0	(4,7)	53	39
LM2	13,9	(1,7)	17	12	35,9	(5,3)	45	28
LM3	14,3	(1,7)	18	12	35,2	(12,6)	54	21
LM4	13,0	(1,5)	16	9	41,2	(12,7)	62	29
LM5	13,8	(1,8)	19	10	40,4	(9,2)	63	27

Temperature and relative humidity in the LTMCM are summarized in the Table 5. According to the preservation index for paper based material and photo storage developed by the Image Permanence Institute (i.e. IPI; http://www.imagepermanenceinstitute.org/), the average temperature and relative humidity obtained in the five indoor locations monitored in the LTMCM involve slow natural aging rate. There is no risk for mold germination and the conditions are recommended for storage of photographic material (Figure 16). However, high values of relative humidity measured in some of the locations (Figure 11 and

Figure 16) involve lower preservation index for paper based materials (i.e. 65 years; Figure 16) than the one obtained from the average values (i.e. 124 years; Figure 16). In addition, the highest conditions involve moderate natural aging rate and conditions not recommendable for the preservation of photographic material. For paper based material and photographic materials, relative humidity above 50% is not recommendable due to fast increase of the natural aging rate.

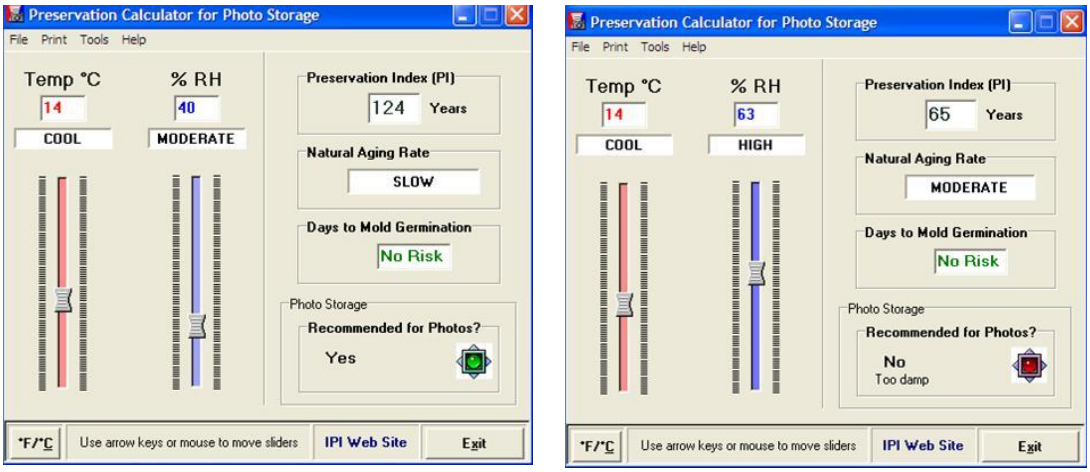

Figure 16: Preservation Index calculator from the Image Permanence Institute. Average (left) and high relative humidity (right) conditions measured in the LTMCM.

4.6 Sampling location comparison

The comparison of the data presented in this report indicates on one hand, that the storage room or depository named LM2 shows the most acceptable environment out of the five sampling locations for the preservation of cultural heritage objects. On the other hand, the worst environment for the preservation of cultural heritage objects is the location LM5.

The location LM2 is a depository room which holds a variety of cultural heritage objects mainly composed of musical instruments. The room is located in the second floor of the building and does not have a window. The EWO dosimeter does not respond, indicating excellent environment concerning photo-oxidant effects on organic materials. The concentration of NO_2, strong oxidant compound with well documented effects on cultural heritage materials (Tétreault, 2003; Harchfield, 2002), and particle deposition value are the lowest of the five sampling locations. Organic acids concentrations are not significantly high (below 100 µg m^{-3}) for an indoor location and it is similar to those obtained in other indoor locations.

On the contrary, the location LM5 is an exhibition room location on the basement, at street level with window facing the street. The concentration of NO_2 in room LM5 is the highest of the study, with a I/O ration close to 1 (i.e. 0.76) which indicates high infiltration of outdoor pollutants. The results obtained from the evaluation of particle deposition show the highest value of the study.

5 Dissemination activities

Different dissemination activities took part within the project and some of the results will be used in further activities after the completion of the project.

5.1 Webpage

A page linked to the webpage of the Lithuanian Theatre, Music and Cinema Museum was designed and created at the beginning of the project (Figure 17). The page is opened to the general public and describes the main objective of the project, short description of the methodology and the contact information from both the Lithuanian and Norwegian partner.

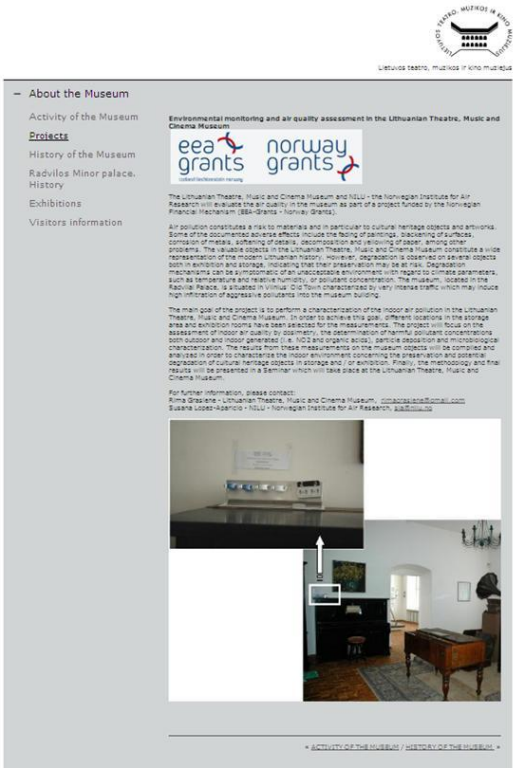

Figure 17: Webpage of the project (http://www.ltmkm.lt/en/about_the_museum/projects.html).

5.2 Project seminar

On 30th June 2010, a final seminar of the project took place in the Lithuanian Theatre, Music and Cinema Museum. The researchers from the Norwegian Institute for Air Research gave a lecture about the importance of air pollution for cultural heritage and a presentation of the main results obtained during the project. The presentations were given under the titles:

- *"Air pollutants in museums"* by Terje Grøntoft
- *"Indoor Air Quality in the Lithuanian Theatre, Music and Cinema Museum - Environmental monitoring and Air Quality Assessment"* by Susana López-Aparicio

Abstracts and presentations are included in the Appendixes of this report.

6 Conclusions

a) The indoor air quality in the studied storage rooms of the LTMCM is "acceptable" and "excellent" concerning the photo-oxidant effects of the environment (i.e. synergistic effects of temperature, relative humidity, UV light, NO_2 and O_3) on organic materials.
b) The indoor air quality in the studied exhibition rooms of the LTMCM varies between "very good" and "excellent" concerning the photo-oxidant effects of the environment (i.e. synergistic effects of temperature, relative humidity, UV light, NO_2 and O_3) on organic materials.
c) Low concentrations of outdoor generated pollutants (i.e. NO_2) were measured in storeroom whereas high concentration was measured in exhibition rooms.
d) The infiltration of outdoor generated pollutants (i.e. NO_2) is similar in rooms facing the street and those facing the backyard which are located in the same floor.
e) High concentration of indoor generated pollutants (i.e. acetic and formic acids) was obtained in one storage room with significant source.
f) The highest concentration of NO_2 (30 µg m^{-3}) and acetic acids (278 µg m^{-3}) may constitute a risk for the preservation of cultural heritage objects.
g) The results obtained by the study of particle deposition indicate high infiltration of particles in rooms with windows facing the streets.
h) Temperature and relative humidity values obtained during three months indicate slow natural aging rate of paper based materials and recommended conditions for the storage of photographic material.
i) The highest relative humidity values measured inside some of the sampling locations indicate moderate natural aging rate and the conditions are not recommended for the storage of photographic material.
j) The storeroom without window shows the most acceptable indoor air quality for the preservation of cultural heritage objects.
k) The gallery room at street level and window facing the street side of the building shows the least acceptable indoor air quality for the preservation of cultural heritage objects.

7 Acknowledgements

This study was made possible thanks to the financial support of “Norway Grants” (NR.2004-LT0009-1NOR-02-011). Special thanks are due to Rima Grasiene and all the colleagues at the Lithuanian Theatre, Music and Cinema museum, responsible for the practical work. Many thanks to Erik Andresen, Nina Dahl and colleagues at the Norwegian Institute for Air Research (NILU) for the preparation and analysis of passive diffusion gas samplers. The author gratefully acknowledge Terje Grøntoft for its collaboration in the project. The early version of this report benefited from the comments by Claudia Hak and Cristina Guerreiro.

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Appendix A
Results Database

Location	EWO response	LEVEL	NO_2	Acetic Acid	Formic Acid	Particle deposition
Units	Light Absorption		µg m^{-3}	µg m^{-3}	µg m^{-3}	%
LM1	0,00369		4,79	389,40	83,43	1,80
LM1	0,00409		4,51	166,79	1,09	1,50
						1,70
						1,40
						1,00
LM1 aver	0,00389	1	4,65	278,09	42,26	1,48
LM1 stdev	0,00028		0,20	157,41	58,22	0,31
LM2	0,00000		0,95	103,04	4,26	0,50
LM2	0,00000		0,96	74,80	1,36	0,50
						0,40
						0,30
						0,10
LM2 aver	0,00000	1	0,95	88,92	2,81	0,36
LM2 stdev	0,00000		0,01	19,97	2,05	0,17
LM3	0,00431		14,17	111,25	9,64	1,00
LM3	0,00431		12,86	76,18	4,35	1,10
						0,90
						1,20
						1,70
LM3 aver	0,00431	1	13,52	93,71	6,99	1,18
LM3 stdev	0,00000		0,93	24,80	3,74	0,31
LM4	0,01628		15,29	67,64	6,27	0,70
LM4	0,01514		15,63	62,48	10,61	0,90
						0,70
						0,80
						0,40
LM4 aver	0,01571	2	15,46	65,06	8,44	0,70
LM4 stdev	0,00081		0,24	3,65	3,07	0,19
LM5	0,01501		27,97	25,73	5,36	2,70
LM5	0,01597		30,20	12,39	1,29	2,00
						1,80
						1,80
						2,20
LM5 aver	0,01549	2	29,08	19,06	3,33	2,10
LM5 stdev	0,00068		1,57	9,43	2,88	0,37

Appendix B
Abstracts - Final Seminar (Vilnius, June 2010)

"Air pollutants in museums"

Terje Grøntoft
Norwegian Institute for Air Research (NILU)

Indoor museum objects are degraded in their contact with the environment. It is an aim for cultural heritage institutions to do preventive conservation that assures optimal environmental conditions, to obtain the lowest possible degradation rate. This will protect the objects and reduce the costs of conservation intervention. Climate conditions (temperature, relative humidity and light /UV) and air pollutants are important properties of the environment. Lack of control with climate and pollutants can increase the degradation rate of the objects. For the best preservation it is generally advisable to keep a stable climate at recommended levels and to reduce the amounts of pollutants to as low levels as possible. To know the environmental conditions it is necessary to do measurements. Measurements of climate and air pollutants in museums can be performed with instruments ranging from the simple and relatively inexpensive to more advanced and expensive instruments that give more detailed information. For their daily routines many museums prefer simple and low cost methods that can be more easily handled by the conservators within the budgets of the institutions. This lecture will present some relatively simple and easy to handle methods for climate and air pollution monitoring and evaluation in museums. In particular there will be focus on passive samplers and dosimeter materials that responds with a readable change to one, or the combination of several, environmental degradation factors. Some examples of results obtained in various different cultural heritage locations in Europe will be given.

"Indoor Air Quality in the Lithuanian Theatre, Music and Cinema Museum - Environmental monitoring and Air Quality Assessment"

Susana López-Aparicio
Norwegian Institute for Air Research (NILU)

The presentation will summarize the main results obtained in the project: "Environmental monitoring and air quality assessment in the Lithuanian Theatre, Music and Cinema Museum" funded by the Norwegian Financial Mechanism (EEA-Grants - Norway Grants). The main goal of the project was to assess the indoor air quality for the preservation of cultural heritage objects both in storage and exhibition. Measurements of environmental parameters were performed in different types of indoor locations and following different methodologies. The EWO dosimeter (Early Warning dosimeter for Organic materials) was used to determine the acceptability of the environment concerning photo-oxidant effects on organic materials. The concentrations of NO_2 (outdoor generated) and organic acids (i.e. acetic and formic acids; indoor generated) were measured by passive diffusion gas samplers, whereas particle deposition was determined by examination of glass slides and subsequent particle quantification. The results were combined with additional information such as temperature, relative humidity and characteristics of the rooms in order to performed a more complete evaluation. Different environmental conditions were observed and possible relationships with the physical characteristic of the room (e.g. presence/absence of window) were established. High concentration of organic acids (acetic and formic acids) was measured in a storeroom with significant source of organic compounds, whereas high concentration of NO_2 was measured in exhibition areas. The results indicated high infiltration of pollutants such as NO_2 and particles through the building envelope. The methodology employed in the project will be explained along with the evaluation of the indoor environment regarding the preservation of cultural heritage objects in the museum.

Appendix C

Presentations – Final Seminar (Vilnius, June 2010)

Air pollutants (and climate) in museums.
Measurement and evaluation methods.

EEA – Norway grants Project.

Measurements in the Lithuanian, Theatre, Music and Cinema Museum.

Vilnius, 30th June, 2010

Terje Grøntoft – Norwegian Institute for Air research , NILU

Lithuanian, Theatre, Music and Cinema Museum.

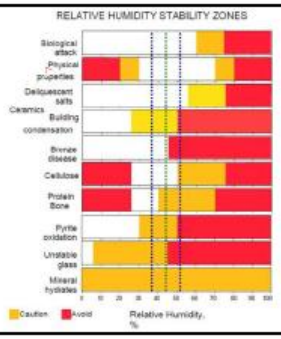
Objects?

- Musical instruments
- Paintings
- Posters
- Film
- Recording instruments
- Cameras
- Clothes
- Dolls - etc.

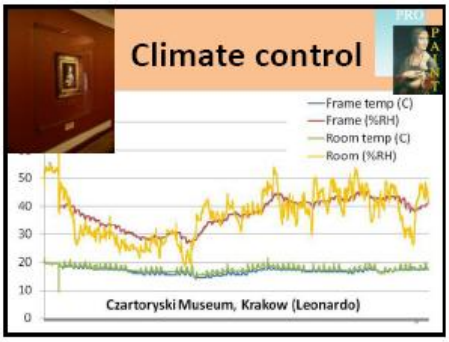
Content

- Climate - levels, effects, measurements
- Pollutants in museums and collections
  A. Presence B. Effects on objects
- Measurements
- Evaluation
- Environmental control and management

Climate



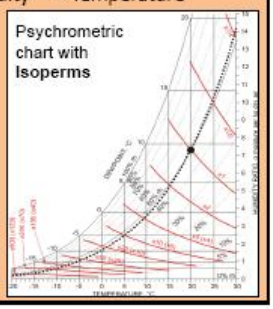
Climate control



✓Relative humidity ✓Temperature

✓Light / UV

Psychrometric chart with **Isoperms**



1

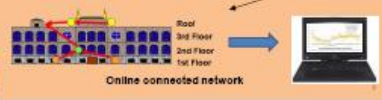
Climate measurements

- Temperature
- Relative humidity

Humidity stripe

Thermo-hygrograph

Thermo-hygrometer



Online connected network

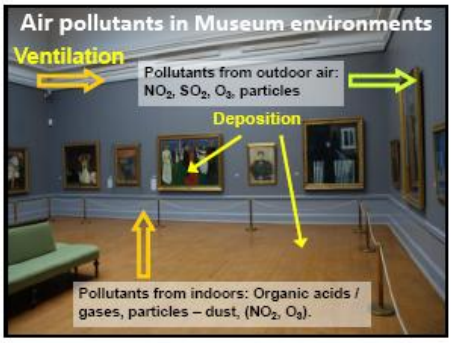
Light /UV

Light check™

Light dosimeters

Light meters

Air pollutants in Museum environments



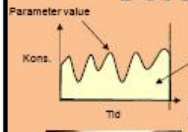
Pollutants and effects

Blades et.al.

	Pollutant	Effect
	SO_2 (Sulphur dioxide)	Tarnishes(corrosion of) metals Damage of paints and dies Embrittles and discolours papers Reduces strength in textiles Attacks photographic materials
	H_2S/ COS (Hydrogen sulphide/ carbonyl sulphide)	Tarnishes metals – especially silver
1.Ox.	NO_2 (Nitrogen dioxide)	Induces fading in textile dyes Reduces strength in textiles Damages photographic film
	O_3 (Ozon)	Cracks rubber Induces fading in dyes Attacks photographic materials Damage books
2.Ao.	Formic acid (Formaldehyde) / Acetic acid	Corrodes some metals, especially lead, zinc and copper alloys with lead. Attack calcareous materials / minerals.
	Acetic acid	May attack paper, pigments and textiles
	Particles	Soiling. Discolouration. Reactive alkaline / acidic particles. Increased humidity on surfaces

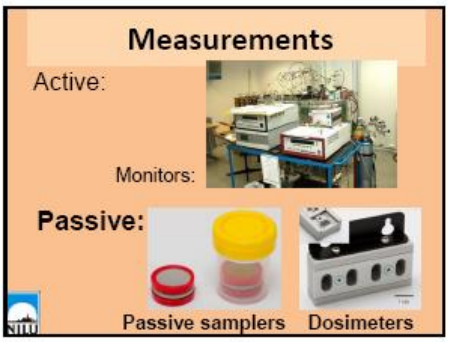
NO_2 (Nitrogen dioxide)	Induces fading in textile dyes Reduces strength in textiles Damages photographic film
O_3 (Ozon)	Cracks rubber Induces fading in dyes Attacks photographic materials Damage books
Formic acid (Formaldehyde) / Acetic acid	Corrodes some metals, especially lead, zinc and copper alloys with lead. Attack calcareous materials / minerals.
Acetic acid	May attack paper, pigments and textiles

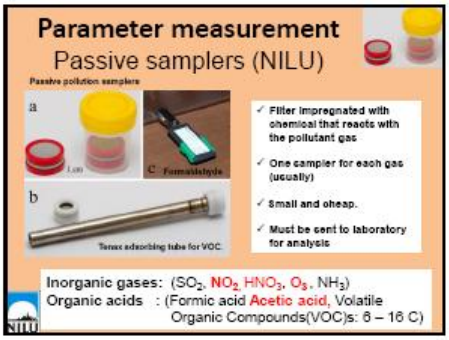
Doses

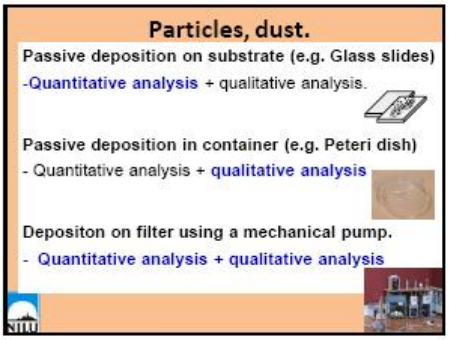


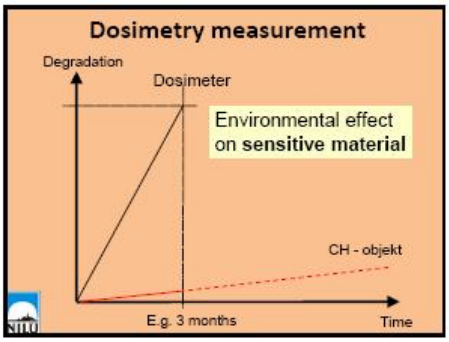
Dose
•
Reaction Rate
(sensitivity)
=
Effect

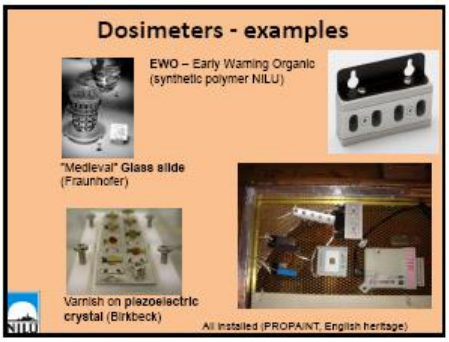

Pollutants in museum environments
How to know?
- Measurements
- (Modelling)
What to do?
- Standards (Threshold levels)
- Preventive measures


Measurements
Active:
Monitors:
Passive:
Passive samplers
Dosimeters


Parameter measurement
Passive samplers (NILU)
Passive pollution samplers
a
b
c Formaldehyde
Tenax adsorbing tube for VOC
✓ Filter impregnated with chemical that reacts with the pollutant gas
✓ One sampler for each gas (usually)
✓ Small and cheap.
✓ Must be sent to laboratory for analysis
Inorganic gases: (SO_2, NO_2, HNO_3, O_3, NH_3)
Organic acids : (Formic acid Acetic acid, Volatile Organic Compounds(VOC)s: 6 – 16 C)


Particles, dust.
Passive deposition on substrate (e.g. Glass slides)
-Quantitative analysis + qualitative analysis.
Passive deposition in container (e.g. Peteri dish)
- Quantitative analysis + qualitative analysis
Depositon on filter using a mechanical pump.
- Quantitative analysis + qualitative analysis


Dosimetry measurement
Degradation
Dosimeter
Environmental effect on sensitive material
CH - objekt
E.g. 3 months
Time


Dosimeters - examples
EWO – Early Warning Organic (synthetic polymer NILU)
"Medieval" Glass slide (Fraunhofer)
Varnish on piezoelectric crystal (Birkbeck)
All installed (PROPAINT, English heritage)

Metal coupons - NILU

Store room – Historical museum in Oslo

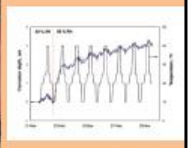
2. Effects measurements - Dosimeters

Metal coupons - OnGuard© (C, P)

- Ag and Cu plated Piezo-electric quartz crystals.
- Recommended response levels for cultural heritage environments.
- Detection limit: 1 ppb
- Responses:
  Cu: RH, T , SO_2, O_3, Cl^- ,HCOOH, CH_3COOH,
  Ag: T, S-compunds (H_2S), Cl^-, (NO_2, O_3)

Corrosion resistance measurement – CORRLOGG© (C, P), EU-FP6

- Principle: Increase in electrical resistance in Fe, Zn, Cu or Ni of a thin metal track applied on an insulating substrate (Due to corrosion)

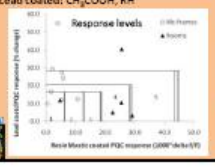


Corrosion logger with a sensor (left) and non-contact data transfer (right)

Piezo electric quartz crystal dosimeters.

"The Birkbeck" PQC (Lead or varnish coated) (C, O, P)

- Varnish or lead coated Piezo-electric Quartz Crystals (PQCs)
- Recommended response levels for cultural heritage environments. (PROPAINT FP6)
- Main responses (PROPAINT-indoor):
  Varnish coated NO_2, T
  Lead coated: CH_3COOH, RH



Sensitive glass – "Fraunhofer glass slide dosimter (GSD)" (P)

- Highly sensitive glass (more K_2O)
- Recommended response levels for cultural heritage environments.
- Main responses: Acidic (PROPAINT-indoor): CH_3COOH

Sensitive polymers – "NILU Early Warning Organic (EWO) dosimeter

- Synthetic polymer (PPO) spin coated on small glass chips.
- Recommended response levels for cultural heritage environments.
- Detection limit: 1-2 ppb
- Responses: Photo-oxidising (MASTER, PROPAINT): NO_2, O_2, UV-light, T

Exposure at location for 3 months

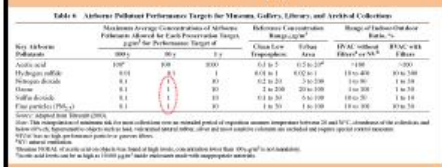
EWO holders

1. Photospectrometer in lab.

What kind of instruments to use?

- Relevance,
- Practicality,
- Easy use
- Easy interpretation
- Availability
- Price

Determination of threshold levels – standards (1)



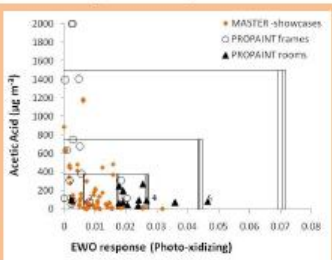
ASHRAE Guideline (2003):

American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2003. Museums, libraries, and archives (chapter 21). *ASHRAE Applications Handbook (SI Edition)*, ASHRAE, Atlanta.

Tétreault, J. 2003. *Airborne Pollutants in Museums, Galleries, and Archives: Risk Assessment, Control Strategies and Preservation Management*, Ottawa: Canadian Conservation Institute.

Photo-oxidizing and acidic pollutants.

Museum rooms, showcaess, Microlimate frames



What to do? - after measurement / diagnosis

1. **Reduce dose:**
   a. Reduce pollutant concentration

E.g:
- ✓ Reduce ventilation to reduce indoor concentrations of "outdoor" pollutants
- ✓ Increase ventilation to remove "indoor"- pollutants
- ✓ Avoid apparatus / materials that emit pollutant gases
- ✓ Reduce (change) light /UV, *T, RH* to desired level.
- ✓ Avoid strong environmental fluctuations.
- ✓ Install absorbers.
- ✓ Install microclimate frames

   b. Reduce exposure time

E.g:
- ✓ Avoid long duration exposure outdoors or indoors in bad environments.
- ✓ Reduce transport time
- ✓ Keep **protecting** microclimate around object (storage bags, frames, showcases etc..

2. **Reduce reaction rate**

E.g:
- ✓ Reduce transport of pollutants to object, - air flow / turbulence close to object
- ✓ Remove dust / clean objects
- ✓ Implement recommended (correct) conservation treatments

Thank you for listening!

Indoor Air Quality in the Lithuanian Theatre, Music and Cinema Museum

Environmental monitoring and Air Quality Assessment

NILU Susana López-Aparicio, Norwegian Institute for Air Research, NILU

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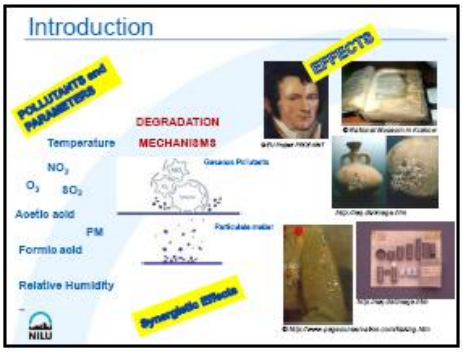
- Acknowledgements

Introduction



Introduction - Objectives

- Characterization of the indoor air pollution in the Lithuanian Theatre, Music and Cinema Museum.
- Measurement and analysis of air pollutants (outdoor and indoor generated) in storage and exhibition rooms.
- Evaluation of the IAQ for the preservation of Cultural Heritage Objects

Methodology

Sampling location

The Lithuanian Theatre, Music and Cinema Museum

Methodology

Sampling location

Methodology — Measurements

- Temperature / Relative Humidity

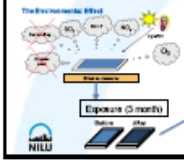
Thermometer and Hygrometer TFA: ± 1ºC and ± 5% RH accuracy

Methodology — Measurements

- Temperature / Relative Humidity
- Dosimeter

EWO – Dosimeter: Early Warning dosimeter for Organic materials

Photo-oxidant effects of the environment (NO_2, O_3, T/RH, UVLight).



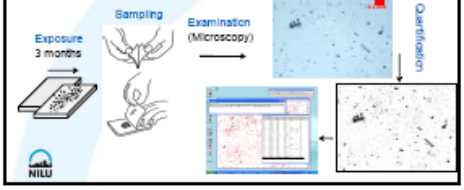
Methodology — Measurements

- Temperature / Relative Humidity
- Dosimeter
- Passive gas samplers

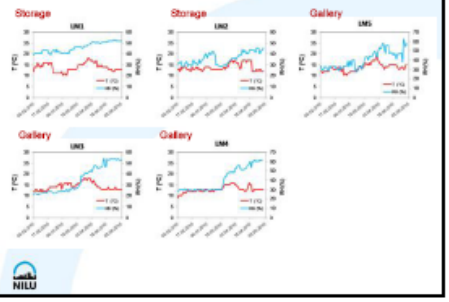
Concentration of NO_2 and Organic acids (Acetic and formic acids)

Methodology — Measurements

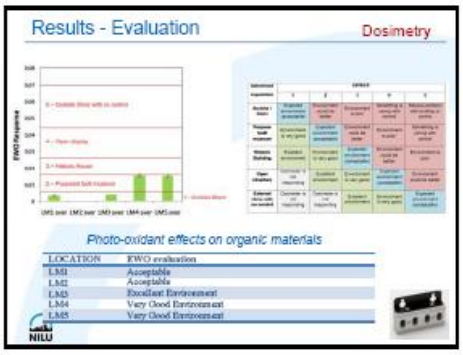
- Temperature / Relative Humidity
- Dosimeter
- Passive gas samplers (NO_2, Organic acids)
- Particulate deposition

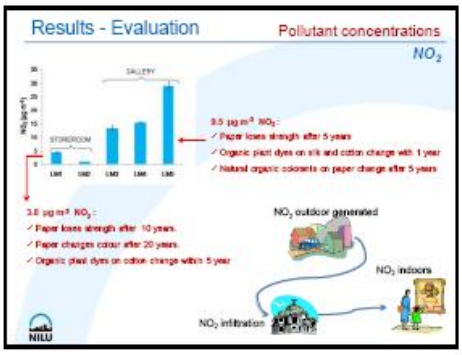


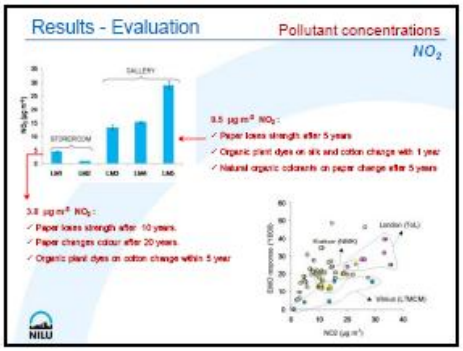
Results - Evaluation — Temperature & Relative Humidity



Results - Evaluation — Temperature & Relative Humidity


Results - Evaluation
Dosimetry
Photo-oxidant effects on organic materials
LOCATION
EWO evaluation
LM1
Acceptable
LM2
Acceptable
LM3
Excellent Environment
LM4
Very Good Environment
LM5
Very Good Environment
NILU


Results - Evaluation
Pollutant concentrations
NO2
GALLERY
STOREROOM
9.5 µg m-3 NO2 :
✓ Paper loses strength after 5 years
✓ Organic plant dyes on silk and cotton change with 1 year
✓ Natural organic colorants on paper change after 5 years
3.8 µg m-3 NO2 :
✓ Paper loses strength after 10 years.
✓ Paper changes colour after 20 years.
✓ Organic plant dyes on cotton change within 5 year
NO2 outdoor generated
NO2 indoors
NO2 infiltration
NILU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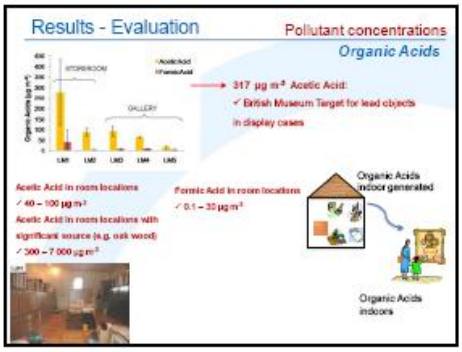
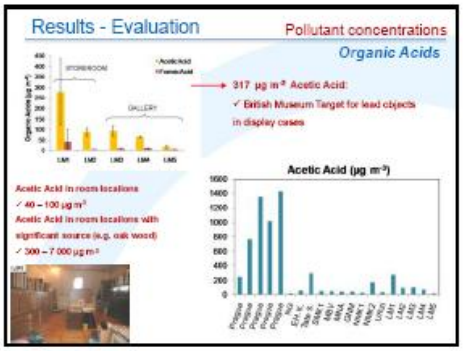
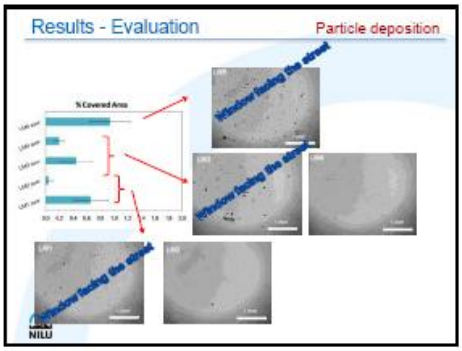
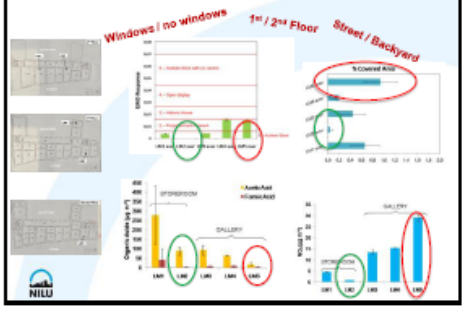
NILU


Results - Evaluation
Pollutant concentrations
Organic Acids
STOREROOM
GALLERY
317 µg m-3 Acetic Acid:
✓ British Museum Target for lead objects in display cases
Acetic Acid in room locations
✓ 40 – 100 µg m-3
Acetic Acid in room locations with significant source (e.g. oak wood)
✓ 500 – 7 000 µg m-3
Formic Acid in room locations
✓ 0.1 – 30 µg m-3
Organic Acids indoor generated
Organic Acids indoors


Results - Evaluation
Pollutant concentrations
Organic Acids
STOREROOM
GALLERY
317 µg m-3 Acetic Acid:
✓ British Museum Target for lead objects in display cases
Acetic Acid in room locations
✓ 40 – 100 µg m-3
Acetic Acid in room locations with significant source (e.g. oak wood)
✓ 500 – 7 000 µg m-3
Acetic Acid (µg m-3)


Results - Evaluation
Particle deposition
% Covered Area
Window facing the street
Window facing the street
Window facing the street
NILU

Summary



Conclusions – 1)

- Photo-oxidant effects of the environment (i.e. synergistic effects of temperature, relative humidity, UV light, NO_2 and O_3) on organic materials.

-The IAQ in the storage rooms is "acceptable" or "excellent"
-The IAQ the studied exhibition rooms varies between "very good" and "excellent".

- Outdoor generated pollutants; High levels of NO_2 were obtained at street level. They may be a risk for cultural heritage objects
- Indoor generated pollutants; High concentration was obtained in a storage room with significant source. Levels of acetic acid may be a risk for metals and paper based material

Conclusions – 2)

- Temperature and relative humidity values obtained during three months indicate slow natural aging rate of paper based materials and recommended conditions for the storage of photographic material.
- High Relative Humidity may be followed up.
- High infiltration of particles in rooms with windows facing the streets.
- The storeroom without window shows the most acceptable IAQ for the preservation of cultural heritage objects.
- The gallery room at street level and window facing the street side of the building shows the least acceptable IAQ for the preservation of cultural heritage objects.

4

Norwegian Institute for Air Research
P.O. Box 100, N-2027 Kjeller, Norway
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TITLE	PROJECT LEADER
Indoor Air Quality in the Lithuanian Theatre, Music and Cinema Museum Environmental Monitoring and Air Quality Assessment	Susana López-Aparicio NILU PROJECT NO. O-109132
AUTHOR(S) Susana López-Aparicio	CLASSIFICATION * A CONTRACT REF.

REPORT PREPARED FOR
Lithuanian Theatre, Music and Cinema Museum
Vilniaus st. 41
LT-01119 VILNIUS
LITAUEN

ABSTRACT
The report summarizes the main results obtained in the project “Environmental monitoring and air quality assessment in the Lithuanian Theatre, Music and Cinema Museum” funded by the Norwegian Financial Mechanism (EEA-Grants – Norway Grants). The main goal of the project was to assess the indoor air quality for the preservation of cultural heritage objects both in storage and exhibition. Measurements of environmental parameters were performed in different types of indoor locations and following different methodologies. High concentration of organic acids (acetic and formic acids) was measured in a storeroom with significant source of organic compounds, whereas high concentration of NO_2 was measured in exhibition areas. The results indicated high infiltration of pollutants such as NO_2 and particles through the building envelope.

NORWEGIAN TITLE
Innendørs luftkvalitet i Lithuanian Theatre, Music and Cinema Museum

KEYWORDS		
Indoor air quality	Lithuanian museum	Organic acids

ABSTRACT (in Norwegian)
Rapporten oppsummerer de viktigste resultatene oppnådd i prosjektet "Miljøovervåking og luftkvalitetsvurdering i Lithuanian Theatre, Music and Cinema Museum" finansiert av den norske finansieringsordningen (EEA-Grants - Norway Grants). Hovedmålet var å vurdere inneklima for bevaring av kulturarvobjekter både i oppbevaring og i galleri. Målinger av miljø-parametre ble utført i ulike innendørsmiljøer med ulike metoder. Høy konsentrasjon av organiske syrer (eddiksyre og maursyre) ble målt i en bod med organiske syrer som kilde, mens høy konsentrasjon av NO_2 ble målt i utstillingsområdet. Resultatene indikerte høy infiltrasjon av forurensninger som NO_2 og partikler gjennom bygningen.

** Classification*
A Unclassified (can be ordered from NILU)
B Restricted distribution
C Classified (not to be distributed)

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