AIR QUALITY MONITORING FOR JORDANIAN MUSEUMS, STORAGES AND ARCHIVES

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Leiden University

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TNO
OBJECTIVES

- Objects at Jordanian museums suffer from deterioration and destruction caused by the different surrounding environmental parameters and by mishandling.

- This study seeks to identify those environmental factors and to replace them with the suitable environmental conditions for the objects displayed or stored, using proper methods which will contribute to the stabilization of these objects.

- Finding out the proper way for displaying and storing objects in their custody.
INTRODUCTION

➢ Environmental factors

- Temperature
- Humidity
- Light
- Particulates (Dust)
- Microorganisms
- Gaseous pollutants

Among these, Gaseous pollutants consider being the most destructive agent.
GASEOUS POLLUTANTS

- Sulfur dioxide: $\text{SO}_2$
- Ozone: $\text{O}_3$
- Nitrogen dioxide: $\text{NO}_2$
- Chlorine: $\text{Cl}_2$
- Hydrogen chloride: $\text{HCl}$
- Acetic acid: $\text{CH}_3\text{COOH}$
- Formaldehyde: $\text{HCHO}$
Leiden University. The university to discover.

Photos (www.greenpeace.com)
THE JORDANIAN MUSEUMS
Als salt Archaeology Museum
1986

Photos By: R. Alghazawi
Dar Alaraya Museum
1886 (1994)

Photos By: R. Alghazawi

Leiden University. The university to discover.
Department of Antiquities (Storage & Archive) 1982

Photos By: R. Alghazawi

Leiden University. The university to discover.
Madaba Archeology Museum
1978

Photos By: R. Alghazawi
Madaba Folklore Museum
1978

Photos By: R. Alghazawi
Museum of Jordanian Heritage
1988

Photos By: R. Alghazawi

Leiden University. The university to discover.
Numismatics Museum
2002

Photos By: R. Alghazawi

Leiden University. The university to discover.
Petra Museum
1994

Photos By: R. Alghazawi
Umm Qies Museum
1987

Photos By: R. Alghazawi

Leiden University. The university to discover.
Why these museums were selected?

- Representing the different geographic and climatic zones.

- Representing all types of materials kept or displayed at the Jordanian museums.

- Representing all types of museum buildings in Jordan.
METHODS

1- Purafil Environmental Reactivity Coupons (ERCs)

2- Purafil Environmental Reactivity Monitors (ERMs)
The Purafil Environmental Reactivity Coupons (ERCs)

How and where these coupons were installed?
Hung inside showroom
Placed inside showcases
Set at the make up air source

“in some museums”
ANALYZING THE COUPONS

Done by
Purafil, Inc

Utilizing
The electronic cathodic reduction method
<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Normal Background Concentrations</th>
<th>Peak Concentrations (Urban Areas)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfur dioxide</td>
<td>6-30 ppb</td>
<td>100-750 ppb</td>
</tr>
<tr>
<td>Ozone</td>
<td>0.4 ppb</td>
<td>20-40 ppb</td>
</tr>
<tr>
<td>Nitrogen dioxide</td>
<td>1.0-1.5 ppb</td>
<td>40-100 ppb</td>
</tr>
<tr>
<td>Chlorine</td>
<td>0.06-0.6 ppb</td>
<td>20-130 ppb</td>
</tr>
<tr>
<td>Hydrogen chloride</td>
<td>20-50 ppb</td>
<td>200-450 ppb</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>4-10 ppb</td>
<td>20-100 ppb</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>3-15 ppb</td>
<td>10-40 ppb</td>
</tr>
<tr>
<td>Hydrogen sulfide</td>
<td>5-10 ppb</td>
<td>100-500 ppb</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class</th>
<th>Air Quality Classification</th>
<th>Corrosion Amount</th>
<th>Class</th>
<th>Air Quality Classification</th>
<th>Corrosion Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Extremely Pure</td>
<td>&lt; 40Å / 30 days</td>
<td>C1</td>
<td>Extremely Pure</td>
<td>&lt; 90Å / 30 days</td>
</tr>
<tr>
<td>S2</td>
<td>Pure</td>
<td>&lt; 100Å / 30 days</td>
<td>C2</td>
<td>Pure</td>
<td>&lt; 150Å / 30 days</td>
</tr>
<tr>
<td>S3</td>
<td>Clean</td>
<td>&lt; 200Å / 30 days</td>
<td>C3</td>
<td>Clean</td>
<td>&lt; 250Å / 30 days</td>
</tr>
<tr>
<td>S4</td>
<td>Slightly Contaminated</td>
<td>&lt; 300Å / 30 days</td>
<td>C4</td>
<td>Slightly Contaminated</td>
<td>&lt; 350Å / 30 days</td>
</tr>
<tr>
<td>S5</td>
<td>Polluted</td>
<td>≥ 300Å / 30 days</td>
<td>C5</td>
<td>Polluted</td>
<td>≥ 350Å / 30 days</td>
</tr>
</tbody>
</table>

**AIR PURITY REQUIREMENTS**

- Archives, Metal Collections, Rare Books: Class S1/C1
- Museums, Museum Storage, Libraries: Class S2/C2
- Historic Houses: Class S3/C3
- Short Term Acceptable: Class S4/C4
- Not Acceptable: Class S5/C5

<table>
<thead>
<tr>
<th>Silver Reactivity Acceptance Criteria</th>
<th>Copper Reactivity Acceptance Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Silver Corrosion Reaction Products</strong></td>
<td><strong>Corrosion Film Thickness</strong></td>
</tr>
<tr>
<td>Silver Chloride, AgCl</td>
<td><em>0Å / 30 days</em></td>
</tr>
<tr>
<td>Silver Sulfide, Ag₂S</td>
<td><em>&lt;50Å / 30 days</em></td>
</tr>
<tr>
<td>Silver Oxide, Ag₂O</td>
<td><em>&lt;50Å / 30 days</em></td>
</tr>
<tr>
<td>Total Silver Corrosion</td>
<td><em>&lt;100Å / 30 days</em></td>
</tr>
<tr>
<td><strong>Copper Corrosion Reaction Products</strong></td>
<td><strong>Corrosion Film Thickness</strong></td>
</tr>
<tr>
<td>Copper Sulfide, Cu₂S</td>
<td><em>0Å / 30 days</em></td>
</tr>
<tr>
<td>Copper Oxide, Cu₂O</td>
<td><em>&lt;150Å / 30 days</em></td>
</tr>
<tr>
<td>Copper Unknowns</td>
<td><em>0Å / 30 days</em></td>
</tr>
<tr>
<td>Total Copper Corrosion</td>
<td><em>&lt;150Å / 30 days</em></td>
</tr>
</tbody>
</table>

RESULTS
### Delineate the locations of the coupons in the Salt museum.

<table>
<thead>
<tr>
<th>Location number</th>
<th>Description of location</th>
<th>The coupon code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Entrance</td>
<td>SM 4</td>
</tr>
<tr>
<td>2</td>
<td>Late Bronze Age Hall</td>
<td>SM 3</td>
</tr>
<tr>
<td>3</td>
<td>Hellenistic - early Islamic Hall</td>
<td>SM 2</td>
</tr>
<tr>
<td>4</td>
<td>The Rural Landscape Middle Islamic</td>
<td>SM 1</td>
</tr>
</tbody>
</table>
Delineate the locations of the coupons in the Dar Alsaraya museum.

<table>
<thead>
<tr>
<th>Location number</th>
<th>Description of location</th>
<th>The coupon code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mosaic Hall</td>
<td>DSM 6</td>
</tr>
<tr>
<td>2</td>
<td>Ancient Period Hall</td>
<td>DSM 1</td>
</tr>
<tr>
<td>3</td>
<td>Islamic Period Hall inside case (glass case)</td>
<td>DSM 4</td>
</tr>
<tr>
<td>4</td>
<td>Metallurgy room inside case</td>
<td>DSM 2</td>
</tr>
<tr>
<td>5</td>
<td>Inside case</td>
<td>DSM 7</td>
</tr>
<tr>
<td>6</td>
<td>Outdoor</td>
<td>DSM 8</td>
</tr>
<tr>
<td>7</td>
<td>Classical periods hall</td>
<td>DSM 3</td>
</tr>
<tr>
<td>8</td>
<td>Sculptures Hall</td>
<td>DSM 5</td>
</tr>
</tbody>
</table>
Delineate the locations of the coupons in the Department of Antiquities (storage and archive).

<table>
<thead>
<tr>
<th>Location number</th>
<th>Description of location</th>
<th>The coupon code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main storage-exit</td>
<td>DAS 5</td>
</tr>
<tr>
<td>2</td>
<td>Storage no. 1</td>
<td>DAS 2</td>
</tr>
<tr>
<td>3</td>
<td>The Cave-inside</td>
<td>DAS 7</td>
</tr>
<tr>
<td>4</td>
<td>Main storage, Entrance</td>
<td>DAS 3</td>
</tr>
<tr>
<td>5</td>
<td>The Care-Entrance</td>
<td>DAS 6</td>
</tr>
<tr>
<td>6</td>
<td>Main storage Back</td>
<td>DAS 4</td>
</tr>
<tr>
<td>7</td>
<td>Archive Drawers</td>
<td>DAA 2</td>
</tr>
<tr>
<td>8</td>
<td>Storage</td>
<td>DAS 1</td>
</tr>
<tr>
<td>9</td>
<td>Archive</td>
<td>DAA 1</td>
</tr>
<tr>
<td>10</td>
<td>Archive Closet</td>
<td>DAA 3</td>
</tr>
</tbody>
</table>
Karak museum

Delineate the locations of the coupons in the Karak museum.

<table>
<thead>
<tr>
<th>Location number</th>
<th>description of location</th>
<th>The coupon code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Hall entrance</td>
<td>KM 1</td>
</tr>
<tr>
<td>2</td>
<td>Entrance</td>
<td>KM 4</td>
</tr>
<tr>
<td>3</td>
<td>Main Hall back side</td>
<td>KM 3</td>
</tr>
<tr>
<td>4</td>
<td>Entrance</td>
<td>KM 5</td>
</tr>
<tr>
<td>5</td>
<td>Main Hall inside closet</td>
<td>KM 2</td>
</tr>
</tbody>
</table>
Delineate the locations of the coupons in the Madaba museum.

<table>
<thead>
<tr>
<th>Location number</th>
<th>description of location</th>
<th>The coupon code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Storage</td>
<td>MM 6</td>
</tr>
<tr>
<td>2</td>
<td>Second show room</td>
<td>MM 5</td>
</tr>
<tr>
<td>3</td>
<td>In show room case</td>
<td>MM 7</td>
</tr>
<tr>
<td>4</td>
<td>Main show room</td>
<td>MM 4</td>
</tr>
</tbody>
</table>
Delineate the locations of the coupons in the Madaba folklore museum.

<table>
<thead>
<tr>
<th>Location number</th>
<th>description of location</th>
<th>The coupon code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Hall</td>
<td>MM 1</td>
</tr>
<tr>
<td>2</td>
<td>Textile Hall</td>
<td>MM 2</td>
</tr>
<tr>
<td>3</td>
<td>Main Hall Entrance</td>
<td>MM 3</td>
</tr>
</tbody>
</table>
Delineate the locations of the coupons in the Museum of Jordanian heritage.

<table>
<thead>
<tr>
<th>Location number</th>
<th>Description of location</th>
<th>The coupon code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Inside show case Lead Sarcophagus</td>
<td>MJH 7</td>
</tr>
<tr>
<td>2</td>
<td>Peasant house</td>
<td>MJH 9</td>
</tr>
<tr>
<td>3</td>
<td>Warehouse (storage)</td>
<td>MJH 10</td>
</tr>
<tr>
<td>4</td>
<td>Inside show case</td>
<td>MJH 6</td>
</tr>
<tr>
<td>5</td>
<td>Entrance</td>
<td>MJH 5</td>
</tr>
<tr>
<td>6</td>
<td>Forth hall Islamic period objects</td>
<td>MJH 8</td>
</tr>
<tr>
<td>7</td>
<td>Outside air</td>
<td>MJH 11</td>
</tr>
<tr>
<td>8</td>
<td>Indoor courtyard</td>
<td>MJH 12</td>
</tr>
<tr>
<td>9</td>
<td>First hall</td>
<td>MJH 13</td>
</tr>
</tbody>
</table>
Delineate the locations of the coupons in the Numismatics museum.

<table>
<thead>
<tr>
<th>Location number</th>
<th>description of location</th>
<th>The coupon code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Outside air Yarmouk</td>
<td>MJH 4</td>
</tr>
<tr>
<td>2</td>
<td>Main Hall Yarmouk Entrance</td>
<td>MJH 1</td>
</tr>
<tr>
<td>3</td>
<td>Main Hall Yarmouk Far corner from entrance</td>
<td>MJH 2</td>
</tr>
<tr>
<td>4</td>
<td>Main Hall Yarmouk Out coming air from (ac)</td>
<td>MJH 3</td>
</tr>
</tbody>
</table>
Delineate the locations of the coupons in the Petra museum.

<table>
<thead>
<tr>
<th>Location number</th>
<th>Description of location</th>
<th>The coupon code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Second Hall</td>
<td>PM 2</td>
</tr>
<tr>
<td>2</td>
<td>First Hall</td>
<td>PM 1</td>
</tr>
</tbody>
</table>
Delineate the locations of the coupons in the Umm Qeis museum.

<table>
<thead>
<tr>
<th>Location number</th>
<th>Description of location</th>
<th>The coupon code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Outside air</td>
<td>UQM1</td>
</tr>
<tr>
<td>2</td>
<td>Main Hall</td>
<td>UQM4</td>
</tr>
<tr>
<td>3</td>
<td>Sculpture Hall</td>
<td>UQM2</td>
</tr>
<tr>
<td>4</td>
<td>Sculptures Hall</td>
<td>UQM3</td>
</tr>
<tr>
<td>5</td>
<td>First showroom</td>
<td>UQM5</td>
</tr>
<tr>
<td>6</td>
<td>Second showroom</td>
<td>UQM6</td>
</tr>
<tr>
<td>7</td>
<td>Second showroom</td>
<td>UQM7</td>
</tr>
</tbody>
</table>
CONCLUSIONS

- If the general reactivity monitoring acceptance criteria of S2/C2 is met, it is generally accepted that this environment may be sufficiently well-controlled as to prevent the decay/deterioration of objects and artifacts - except in cases where active sulfur and/or chlorine contamination is present – although, for archives, metal collections, and rare book storage where a Class S1/C1 is the recommended standard.

- The detection of sulfur and/or chlorine contamination is particularly problematic for metal collections, photographic images, various paper types, and colorants.

- The detection of a silver sulfide (Ag₂S) film without a corresponding copper sulfide (Cu₂S) film usually indicates the presence of oxidized forms of sulfur such as sulfur dioxide (SO₂) and sulfur trioxide (SO₃).
CONCLUSIONS

- When both films are present and the amount of Cu$_2$S is greater than 50% of the total corrosion, this is further evidence of the presence of active sulfur compounds in the subject environment.

- The presence of chloride corrosion (AgCl) indicates the presence of (an) inorganic chlorine compound(s), e.g., chlorine (Cl$_2$), chlorine dioxide (ClO$_2$), hydrogen chloride (HCl).
Differentiated of the monitored museums conditions.

<table>
<thead>
<tr>
<th>Museum</th>
<th>Good (acceptable)</th>
<th>Medium</th>
<th>Bad (not acceptable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Alsalt museum</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Dar Alsaraya museum</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DoA (Storage and Archive)</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Karak museum</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Madaba archaeological museum</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Madaba folklore museum</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The museum of Jordanian heritage</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Numismatics museum</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Petra museum</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Umm Qeis museum</td>
<td></td>
<td></td>
<td>*</td>
</tr>
</tbody>
</table>
RECOMMENDATIONS

- It is further recommended that reactivity monitoring be continued - either with ERCs, or the OnGuard 3000 Atmospheric Corrosion Monitor.

- It is recommended to place additional sets of ERCs in the makeup air handlers and inside the facility to determine if and where these contaminants are being distributed throughout the facility.

- Hence, this research has a limited time for the measurement period, which was made at winter time, consequently, it is recommended for further investigations during the summer season, in order to compare the results and determine whether if there are any changes between the two season’s results.

- Finally, it is recommended that a comprehensive air pollution research to take a place at the rest of the museums in Jordan.
ACKNOWLEDGEMENT

- Twin Filter, Inc. Zaandam, The Netherlands

- Purafil, Inc. Georgia, USA.
THANK YOU FOR YOUR ATTENTION