

Monitoring of Atmospheric Pollutants Carpet Museum of Iran for Proactive Protection Carpet Museum

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Abstract: Air pollution refers to any pollutant, whether solid, liquid or gas and radioactive and non-radioactive radiation in the air to the amount and length of time which threatens quality of life for humans and other organisms or damages artifacts and properties. The origin and health effects of air pollutants are numerous it is impractical to review all of them. Generally, a group of air pollutants called criteria air pollutants including carbon monoxide, ozone, particulate matter, nitrogen dioxide and sulfur dioxide are taken into consideration. Due to its special geographical and cultural conditions, Iran is able to produce hand-woven carpets. Carpet is one of the national heritage of Iran. Carpet Museum of Iran has been established for storage of historical carpets. Movement of visitors and museum staff is higher in exhibition halls. Huge amount of pollutants which are non-compliant with natural mechanisms is released in the air. These pollutants have devastating effects on humans and artifacts existing in museums. Considering the effect of air pollution, prediction of pollution index can help decision-making. Over the years, studies have been conducted on pollution of the environment surrounding objects and humans. Given the importance of pollution control and its important role in environmental management, it is essential to identify major pollutants in museums and take actions on their effective control. Important factors such as dust, carbon oxides, sulfur oxides and nitrogen oxides must be analyzed continuously in real time to control them in case of incompliance with the standards. The first step in environmental control is to minimize corruption of artifacts and materials; the second step is to stabilize artifacts against pollution of the storage area. Using statistical methods and sampling as well as archival and laboratory studies, this study identifies, measures and monitors atmospheric pollutions of museums in order to determine the most functional method for storage of carpets. For this purpose, Carpet Museum of Iran is chosen for implementing these methods.

Key words: Atmospheric pollutants, protection, measurement, carpet museum of Iran, exhibition halls

INTRODUCTION

Throughout the centuries, Iranian carpets have been representing Iranian art and culture. Currently, Iranian carpets are kept in different museums, collections and galleries such as the Carpet Museum of Iran in Tehran, Shiraz Carpet Museum and the Museum of Astan Quds Razavi. Protection of this rich cultural heritage is necessary to defend fundamental rights of future generations. In this regard, the first step is to identify harmful factors and proactive protection against these factors. Environmental factors (light, temperature, humidity and atmospheric pollutants) are the most important damaging factors, among which atmospheric pollutants are the worst (Purafil, 2004). Carpets can be seriously threatened by pollutants existing in the

atmosphere such as NO_x and SO₂, O₃, organic vapor and ingredients of cleaners. These gases not only change color but also cause corrosion, decay and mechanical changes (Bacci *et al.*, 2008). Gases, vapors and solid particles in the environment are one of the signs of decay and erosion of artifacts; therefore, enough information is required on these pollutants, their origin and effects (Mohsenian, 2010). Air pollution is a major cause of decline of artifacts. Destruction of artifacts depends on environmental conditions (Reddy *et al.*, 2005). Due to air pollution, exhibition halls need control and main focus. Gases, vapors and solid particles in the environment are one of the signs of decay and erosion of artifacts; therefore, enough information is required on these pollutants, their origin and effects. Eventually, it is essential to improve conditions and reduce pollution of museums.

Objectives:

- Identify major pollutants in the Carpet Museum of Iran
- Identify and determine the type of damages caused by pollutants in the carpets
- Proactive protection of museum carpets against atmospheric pollutants

Questions:

- What are the origins of pollutants existing in Carpet Museum of Iran?
- What are the main atmospheric pollutants in the museum?

MATERIALS AND METHODS

Carpet museum of Iran: Carpet Museum of Iran is located on the north side of Laleh Park in North Kargar Avenue, Fatemi Street intersection. The museum was opened on 11 February 1978. Building of the Carpet Museum of Iran is architecturally stylish and impressive; exterior decorations resemble looms. Exhibition area (3400 m²) includes two halls used to display a variety of hand-woven carpets and rugs. Ground-level floor is used for permanent exhibition and the upper hall is used for temporary exhibitions of rugs and carpets. Carpet Museum of Iran contains the most valuable collection of Iranian carpets since 9th century AD to the present. It is a rich source of research for scholars and art lovers. Usually, about 135 masterpieces of Iranian carpets from important weaving centers such as Kashan, Kerman, Isfahan, Tabriz, Khorasan and Kurdistan are exhibited in the ground-level hall. Located in one of the high traffic areas, atmospheric pollutants enter the museum building. Floors of the halls are covered with felt carpet; carpets and rugs are exhibited in all parts of the ground floor, both horizontally on the floor and vertically along the walls.

Atmospheric pollutants: Increasing growth of cities along with industrial life has caused comfort and convenience as well as new problems for human. One of these problems is air pollution. Air pollution is one of the most important factors influencing destruction and erosion of artifacts directly or indirectly; growth of industries and industrial life is consequently followed by environmental pollutions, particularly air pollution in large and industrial cities. Air pollution is thought to be merely expanded in outdoor areas, while in some cases, indoor air pollution is several times higher than outdoor pollution. It is believed that air pollution comes only from industries and vehicle exhaust. In general, there are four major sources of air pollution in indoor environments:

- Combustion
- Building materials
- Soil
- Bio-aerosols (Sinha *et al.*, 2006)

The American Environmental Protection Agency (EPA) has generally chosen six major pollutants and divided them into two categories: primary and secondary. Primary pollutants are substances which are imported directly into the ambient air; these pollutants include carbon monoxide (CO), nitrogen dioxide (NO₂), sulfur dioxide (SO₂), particulate matter with a diameter <10 μ (PM) and lead (Pb). Secondary pollutants refer to substances which result from interactions in the air around the Earth such as ozone (O₃). Photochemical smog is another pollutant which results from effect of sunlight on pollutants caused by human industrial activities. For a long time, smog was thought to result from burning coal or other fossil fuels in the form of a mixture of smoke and sulfur dioxide. Since 1950, scientists identified a different kind of smog called as photochemical smog which is a toxic mixture of different pollutants such as nitrogen oxides, tropospheric ozone (Tropospheric ozone, sometimes called as bad ozone, is a human pollution which results from internal combustion engines burning petrol and power plants burning coal. Exhaust from cars and industrial pollutants spread NO_x (nitrogen monoxide and nitrogen dioxide) and volatile organic compounds (VOC). NO_x and VOC form tropospheric ozone by chemical reaction with oxygen during a sunny and dry day, usually mid-summer or early autumn) and volatile organic compounds. All of these substances are oxidizing agents and they strongly react; that is why they are considered as one of the most important atmospheric pollutants.

Where do atmospheric pollutants originate?: In this case, the focus is on artifacts polluted with particles which are suspended in the air. Type of particles depends on position and function of the museum. In case of museums which are located in urban areas or near industrial areas, polluted air threatens all objects of any material. Environmental and atmospheric pollutions refer to pollutants such as sulfur dioxide, nitrogen oxides, ozone, hydrogen sulfur, soot and dust which tarnish the organic materials by acidic transfer and cause decay of objects such as textiles and weavings stored in museums (Shelley, 1987). Two major factors influencing the concentration of indoor pollutants include: people and pets which produce carbon dioxide, moisture, odors and microbes as a natural biological process; more importantly, combustion of appliances (stove, artificial

intelligence of R-furnace, fireplace, wood stove), construction materials (used in building, furniture and insulation), tobacco and fine soil around the building (Fisk *et al.*, 1987). Pollution caused by any reason leads to destruction of material (Mohsenian, 2010). Sucking devices which are used for removing soot or dust and sand particles are helpless in the case of sulphurous gases. Sulphurous gases which are important causes of destruction include:

- Hydrogen sulfide (H₂S)
- Sulfur gas or sulfur anhydride (SO₂)

In case of long-time exposure to objects made of organic materials such as carpets and textiles, these gases lead to decay. Sulfur dioxide is one of the most important pollutants. Sulfur dioxide mostly exists in large industrial cities. Polluted atmospheres of urban areas and surroundings have different amounts of sulfur dioxide resulting from fossil fuels. Oxidation of this element produces sulfuric acid and leads to higher exposure of atmospheric pollutants in the form of surface sediments, large and small holes, cracks, crevices and dark surfaces. Aerosols can settle on surfaces by atmospheric conditions, wind and water and pollute them. In this way, they can affect their beauty and cause favorable conditions for their oxidation. One of the most common cause of pollution is claimed to be soil which produces abundant fat, ash, soot and silica crystals. Industrial pollution emitted by construction works and pollution caused by machinery and a wide range of other substances which harm the museum are divided into gaseous and dust pollutions (Carr, 1999). This suggests that common pollutants exist for cellulosic materials and organic materials such as textiles and weavings (Tetreault, 2012). Atmospheric pollutions and aerosols existing in the Carpet Museum can be caused by external sources such as soot, vehicle exhaust gases, ozone and polluting sources inside the storage space such as wood, recycled plastic, rubber, paper, inferior cardboard and freshly painted walls which release harmful vapors into the air. These pollutions accelerate chemical and biological destruction of weavings. In addition, smoking in the storage and use of different sprays can also cause contaminant particles sit on weavings which leads to irreparable damages (Heidari, 2009). Moreover, compounds such as acetaldehyde, acetic acid, formaldehyde, formic acid and volatile organic compounds evolved from coatings, adhesives and sealants used in museums can cause destruction of objects (Grzywacz, 2006). The materials used for decorations and ventilation conditions also influence

concentrations of pollutants (Xu and Wu, 2012). It is noteworthy that many pollutants of museums can be derived from objects themselves. Emissions of raw material of the carpets can seriously affect indoor air quality, depending on the type of material. Some pollutants result from gradual destruction of the materials used in construction of showcases. Some pollutants are photochemical oxidants which lead to degradation of organic dyes (Grzywacz, 2006). Textiles damages come from various sources including unstable environmental conditions, coloring with high humidity and exposure to excessive light which causes discoloration and fading of colors. Some colors are inherently unstable and may cause serious damage to the carpet. Emission of acetic acid and formaldehyde is a major concern in textiles.

Air pollution at the museum: Primary responsibility of a museum is to ensure that its collections are preserved for future generations (Reddy *et al.*, 2005). In general, air pollution of the museums results from their condition, performance, installed equipment, weather, systems used in the building, construction techniques, sources of emissions, activity of employees and quality of outdoor air (Sinha *et al.*, 2006). Effect of indoor air pollution threatens health of residents and causes variations in the surface and appearance of objects. Gases such as nitrogen dioxide, sulfur dioxide and ozone are known as factors of destruction and damage of cultural, historical and art objects. These pollutants mainly originate from outdoor air pollution.

RESULTS AND DISCUSSION

Atmospheric pollutants and their effect on carpets: Antiquities are precious treasures and obvious heritage of a country. It is primarily essential to restore these artifacts and protect them permanently. Condition of an object depends on two major factors, ingredients which are extremely varied and conditions of the storage. Based on their organic or inorganic origins, the materials used can be divided into two major groups: organic materials and inorganic materials (Lister, 1996). Organic materials are more corruptible, although there is no substance which can remain stable in all circumstances (Sousa *et al.*, 2008). Made of organic materials, weavings have historically played an important role in human life. Based on their applications, different types of weavings are produced by using diverse techniques and raw materials. Considering very sensitive nature and high susceptibility of weavings to environmental conditions, they need better protection and preservation (Kareem, 2010). In addition to water vapor, atmosphere contains many

contaminants which are very harmful (Schober, 1991) and significantly contribute to destruction of weavings (Perkins *et al.*, 1999). Since nineteenth century, air pollution has a major role in destruction of cultural property. Reaction of moisture and emissions of factories, coal smoke in large cities and exhaust fumes of vehicles produce acidic compounds which destroy weavings continuously. Artefacts can be seriously threatened by pollutants existing in the atmosphere which are often indoor, such as NO_x, SO₂, O₃, organic vapors and ingredients in cleaners. These gases not only change color of artifacts but also cause mechanical changes (Bacci *et al.*, 2008). In this regard, it is essential to consider damages caused by gaseous pollutants emitted from inappropriate materials. In addition to gaseous pollutants, dust and smoke also damage objects existing in indoor and outdoor spaces. Level of outdoor air pollution including particulate matter, sulfur dioxide, nitrogen oxides, ammonia, aldehydes and oxidants influence indoor air quality in terms of various parameters such as temperature and Relative Humidity (RH) when it is emitted in background environment. Weather conditions associated with indoor air pollution are main reasons for decline of objects (Reddy *et al.*, 2005); in addition to climate changes, photo-oxidation and air pollution are other environmental reasons of chemical damages to the objects. The polluted air causes deterioration of objects. Level of deterioration depends on environmental conditions. To prevent damage from air pollution, environmental control is required to minimize corruption of artifacts and materials and increase stability of the artifacts against environmental pollution (Reddy *et al.*, 2005). Weaving are influenced by dust and particulate matter and experience physical abrasion and erosion. Dust and pollutants can increase chemical damage (Berry, 2003). Often, decay of weavings can be attributed to the action of sulfuric acid which results from local coal stoves and ovens (Lister, 1996). Weavings can also absorb sulfur dioxide which causes decay of weavings, particularly cotton weavings. Air flows around the carpet; therefore, the carpet is influenced by various contaminants existing in the air (Schober, 1991). Sulfurs are the most harmful air pollution for carpet because they are considered as the most important cause of weakness of carpets. All carpets must be washed and cleaned after a few years due to the constant exposure to types of pollution. The adjacent air is polluting; dust particles sink amidst the carpet (Zholeh, 2011). They are combined with water vapor in the air and converted to sulfuric acid (Henry, 2012). In long-term, this leads to dirtiness and

darkening of the carpet surface. Fine particles in the form of a thin layer penetrate into the carpet. In long-term, this leads to dirtiness and darkening of the carpet surface and even decay of the carpet. Dust always exist in the air in the form of several compounds and may penetrate into the carpet as iron particles, carbon, alumina and other materials.

Accumulation of dust and dirt on the carpet provides a good place for insects such as moths which can chew up and destroy wool fibers (Zholeh, 2011). Harmful gases which are released in the air by combustion of conventional fuels cause embrittlement of textiles. In the meantime, cooperation of pollutants (Table 1) and other parameters such as temperature, relative humidity and light accelerate decay and destruction of textiles.

Monitoring of atmospheric pollutants in carpet museum of Iran: To monitor atmospheric pollutants in Carpet Museum of Iran, measurements were done in exhibition halls in summer and winter of 2014, four times per month at 10-12 a.m. using LSI (Fig. 1).

For both summer and winter, twelve measurements were done in collaboration with the Environment Department of Shiraz University to determine the type and amount of pollutants. The identified pollutants included sulfur dioxide, ozone, particulate matter, carbon monoxide, nitrogen oxides, hydrogen sulfide and formaldehyde; their values are listed in the Table 2-4 and Fig. 2-10.

Table 1: Emission of pollutants in the environment

Source	Emission of pollutants
Sources of atmospheric pollutants	Pollution resulting from industrialization, material ejected from exhaust machinery
	Emissions from materials used in the environment
	Emissions from materials used in production of artifacts and objects



Fig. 1: LSI for measuring atmospheric pollutants

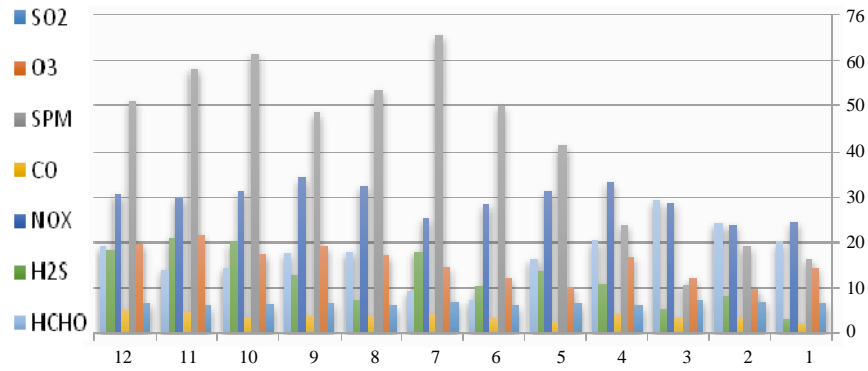


Fig. 2: Pollutants existing in winter in the Carpet Museum of Iran

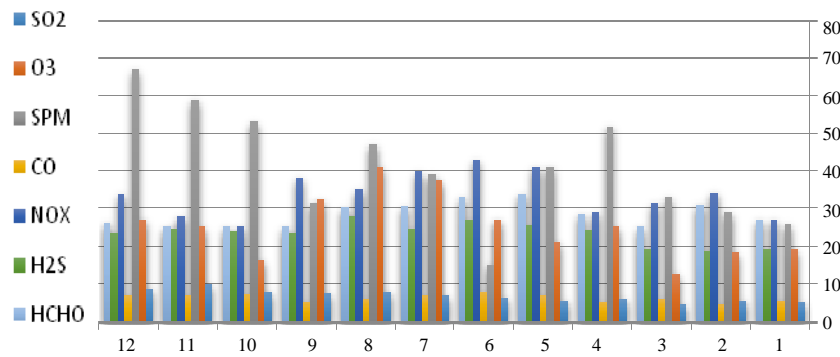


Fig. 3: Pollutants existing in summer in the Carpet Museum of Iran

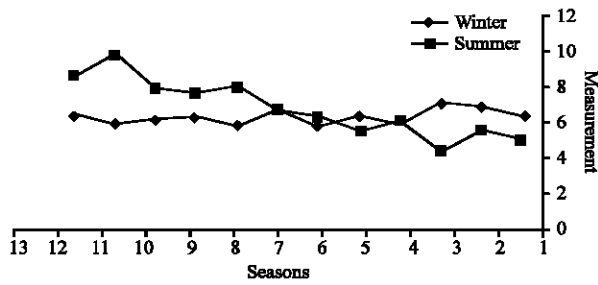


Fig. 4: Measurement of SO₂ (ppb) in winter and summer in Carpet Museum of Iran

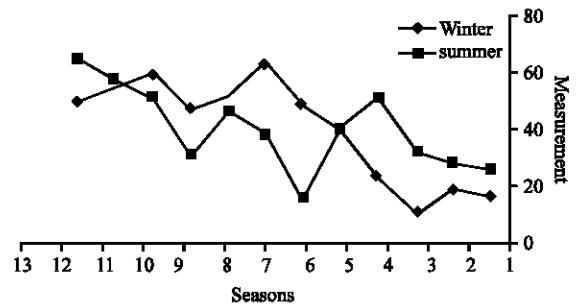


Fig. 6: Measurement of SPM (pm-10) in winter and summer in Carpet Museum of Iran

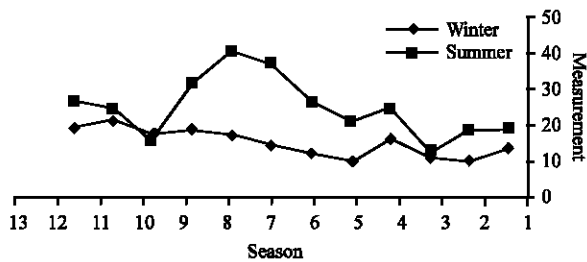


Fig. 5: Measurement of O₃ (ppb) in winter and summer in Carpet Museum of Iran

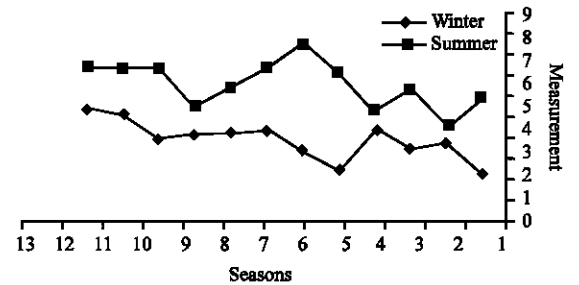


Fig. 7: Measurement of CO (ppb) in winter and summer in Carpet Museum of Iran

Table 2: Pollutants existing in winter in the Carpet Museum of Iran

SO ₂	O ₃	SPM	CO	NO _x	H ₂ S	HCHO
6.38	14.03	16.30	2.08	24.32	3.00	19.94
6.94	9.81	19.18	3.45	23.90	8.00	24.17
7.09	12.02	10.51	3.27	28.60	5.40	29.18
5.93	16.81	23.94	4.11	33.13	11.00	20.32
6.43	10.12	41.13	2.32	31.20	13.70	16.10
5.8	12.23	50.01	3.17	28.29	10.19	7.00
6.72	14.51	65.49	4.10	25.29	18.01	9.11
5.89	17.12	53.51	4.01	32.41	7.17	18.00
6.41	19.11	48.60	3.91	34.27	12.75	17.74
6.24	17.31	61.40	3.71	31.16	19.90	14.18
5.99	21.61	58.12	4.87	29.70	21.00	13.91
6.43	19.78	51.04	5.11	30.50	18.13	19.21

Table 3: Pollutants existing in summer in the Carpet Museum of Iran

SO ₂	O ₃	SPM	CO	NO _x	H ₂ S	HCHO
5.12	19.01	25.85	5.6	27.10	19.33	27.00
5.61	18.33	29.00	4.32	34.30	18.90	31.12
4.43	12.81	33.03	5.97	31.70	19.03	25.14
6.19	25.14	52.17	5.08	29.16	24.30	28.70
5.57	21.33	41.01	6.78	41.17	25.41	34.01
6.38	27.20	15.07	8.09	43.10	27.14	33.12
6.81	37.70	39.17	7.00	40.11	24.71	30.81
8.12	41.00	47.10	6.12	35.17	28.16	30.33
7.75	32.41	31.71	5.20	38.41	23.60	25.19
8.00	16.21	53.12	7.01	25.19	23.99	25.37
9.91	25.04	59.10	6.91	27.91	24.81	25.06
8.71	27.00	67.00	6.99	34.03	23.73	26.46

Table 4: Comparison of mean of pollutants in Carpet Museum of Iran in winter and summer

Air pollutants	Summer			Winter		
	Min.	Max.	Average SD	Min.	Max.	Average SD
SO ₂ (ppb)	4.43	9.91	6.88 1	5.80	7.09	6.35 1
O ₃ (ppb)	12.81	41.00	25.26 1	9.81	21.61	15.37 1
SPM (pm-10)	15.07	67.00	41.11 1	10.51	65.49	41.60 1
CO (ppb)	4.32	8.09	6.25 1	2.08	5.11	3.67 1
NO _x (ppb)	25.19	43.10	33.94 1	23.90	34.27	29.39 1
H ₂ S (ppb)	18.90	28.16	23.59 1	3.00	19.90	12.35 1
HCHO (ppb)	25.06	34.01	28.52 1	7.00	29.18	17.40 1

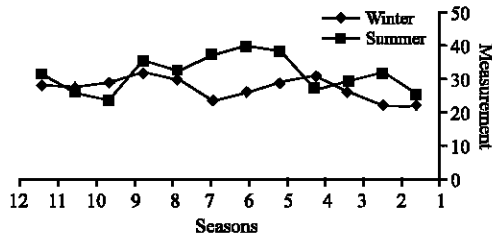


Fig. 8: Measurement of NO_x (ppb) in winter and summer in Carpet Museum of Iran

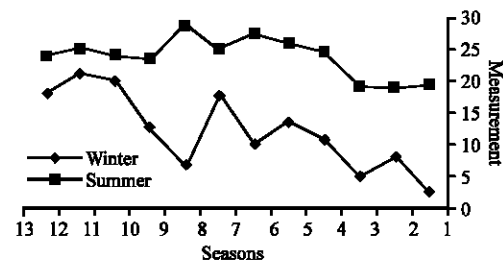


Fig. 9: Measurement of H₂S (ppm) in winter and summer in Carpet Museum of Iran

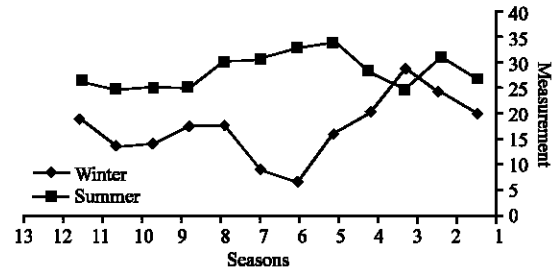


Fig. 10: Measurement of HCHO (ppm) in winter and summer in Carpet Museum of Iran

CONCLUSION

Cultural-historical relics can be preserved in museums by meeting standard environmental conditions for optimal preservation and protection. To identify harmful elements in Carpet Museum of Iran in order to eliminate or minimize erosive elements, it is essential to identify environmental pollutants such as SO₂, O₃, CO, NO_x, H₂S, HCHO and particulate matter. On the other hand, studies conducted in Iran so far on causes of air pollution and its effect on destruction of historical monuments is more focused on application of the results of information collected from organizations related to measurement of air pollution, such as the Environmental Protection Agency in the cities. Given that the level of air pollution is different in indoor and outdoor spaces, this information cannot be used for artifacts existing in museums. Therefore, measurement and control of indoor air pollution needs appropriate measurement methods in museums and exhibition halls used by preservationists in proactive protection of the artifacts existing in the Carpet Museum of Iran. Based on the principle that “prevention is better than cure”, it is essential to ensure permanent safety and health of cultural and historical artifacts. Carpets must be stored in clean spaces with good air quality without presence of pollutants. In fact, carpet storage is a science which is consistent with environmental management, resulting in a healthy environment inside the building. Solutions are suggested to reduce indoor pollution in the Carpet Museum of Iran:

- Understanding of the standard preservation of museum collections against air pollution (NPS).
- Pollutants in the air like smog and cigarette smoke are also harmful for carpets. Properly installed air handling units equipped with the best highly efficient air filters (HEPA filters) are required throughout the building where the carpets are stored to reduce chemicals and pollutants which cause stain, bleaching or weakening of the fabrics

- It is essential to inspect and replace air filters at least once a month
- It is essential to clean surfaces, halls and storages, prevent accumulation of dust in these environments and use vacuum cleaners continuously
- It is essential to inspect openings and seals around doors and windows continually and regularly
- It is essential to use a doormat before entering the halls to prevent soil
- Acidic pollutants and solid particles are the most harmful elements in storages; through environmental management strategies, these harmful factors can be reduced in the environment
- If these solutions are not applicable for any reason, it is essential to use a closed system for storage of textiles

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