Chemistry International 4(2) (2018) 136-145

International Scientific Organization
http://iscientific.org/
Chemistry International
www.bosaljournals.com/chemint/

Atmospheric deposition: Effects on sculptures

Francis Olawale Abulude[1,2,*], Dada Nathaniel Ogunmola[3], Mojisola Mary Alabi[3] and Yusuf Abdulrasheed[2,4]

[1]Science and Education Development Institute, Akure, Ondo State, Nigeria
[2]Department of Chemistry, Federal University of Technology, Minna, Niger State, Nigeria
[3]National Commission for Museum and Monuments, Akure, Ondo State, Nigeria
[4]Faculty of Agriculture, University of Ilorin Sugar Research Institute, Ilorin, Kwara State, Nigeria
*Corresponding author's E. mail: walefut@gmail.com

A R T I C L E I N F O

Article type:
Research article
Article history:
Received January 2018
Accepted March 2018
April 2018 Issue
Keywords:
Atmospheric deposition
Acid rain
Sculpture
Metal
Adverse effect
Maintenance

A B S T R A C T

Public concern over the deleterious effects of atmospheric deposition (AD) has grown rapidly due to its adverse effects (teratogenicity, toxicity, and carcinogenicity) to human, animals, and materials. The aim of this review is to describe the effect of the AD on sculptures, measures for its reduction, and case studies on maintenances of sculptures against the AD. To this end, a step-by-step review is outlined to discuss the harmful effect of AD contamination on many important sculptures. The review paper is also extended to describe preventive steps to reduce AD on sculptures to help reduce the risks associated with AD.

Capsule Summary: This review was undertaken to provide the information on the effect of atmospheric deposition on sculpture. To this end, a step-by-step review outlined the effect of AD on sculptures and suggestion to reduce the AD effect.

Cite This Article As: F. O. Abulude, D. N. Ogunmola, M. M. Alabi and Y. Abdulrasheed. Atmospheric deposition: Effects on sculptures. Chemistry International 4(2) (2018) 136-145.

INTRODUCTION

The sculpture is a branch of the visual arts and it is a plastic art. Sculptures are used to describe large works, which are known as monumental sculpture. The sculpture is associated with religion (ancient Greek art), culture, and public art.

The sculptures are made of different classic materials, such as metal, pottery, wood, bronze, stone, bone, gold, silver, jade, and ivory. Other, less expensive materials are hardwoods (such as oak, box/boxwood, and lime/linden); terracotta and other ceramics, wax), and cast metals such as pewter and zinc (spelter). Sculptures are painted, waxed, oiled to preserve them (Steiger, 2015).

MATERIALS USED IN SCULPTURE

Metal

Most popular metals used for sculptures are bronze and related copper alloys. A bronze sculpture made of its alloys is ductile when compared to various ceramic or stone materials. Gold is a softer precious metal, and useful in jewelry. It is with malleable and can be shaped (casting) in any form. Casting is a process by which a liquid material (bronze, copper, glass, aluminum, iron) is (usually) poured

into a mold (desired shape), and then allowed to solidify. This process is most often used for making complex shapes that would be otherwise difficult or uneconomical to make by other methods (Rao et al., 2014).

Stone

The rough natural stone is used in making stone sculpture. This has been used by earliest societies. Part of the earliest form was the engraving of images on rock surfaces by incising, pecking, carving, and abrading. Stones are used in monuments and architectural sculptures, which are attached to buildings (Rao et al., 2014).

Wood

Wood is widely used in wood carving. It has disadvantages, of being vulnerable to decay, insect damage, and fire if compared to other materials in sculpture making. Outdoor wood sculpture does not last long in most parts of the world. Wood is commonly used in African, Chinese, Japanese, and Oceania cultures. Wood is light, suitable for masks, easier to work than stone, can be painted, and can be plastered to protect the sculpture from pollution (Rao et al., 2014; Steiger, 2015).

Pottery

The use of pottery is old in sculpture making. Sculptors build small preliminary works called maquettes of ephemeral materials such as plaster of Paris, wax, unfired clay, or plasticine. African cultures have produced pottery which combines a function as a vessel with a sculptural form, and small figurines have often been as popular as they are in modern Western culture (Rao et al., 2014).

Glass

Many working methods in sculpture making have made use of glass in recent development. It can be carved, with little or no difficulty. Hot casting can be done by ladling molten glass into molds that have been created by pressing shapes into the sand, carved graphite or detailed plaster/silica molds. Kiln casting glass involves heating chunks of glass in a kiln until they are liquid and flow into a waiting mold below it in the kiln. Glass can also be blown and/or hot sculpted with hand tools either as a solid mass or as part of a blown object (Rao et al., 2014).

AIR POLLUTION

Air pollution is a number of different ways pollution exists in the air. On a global scale, air pollution is discussed in relation to carbon dioxide (CO_2) and other greenhouse gas emissions (Howard-McGuire (2013). Greenhouse gas emissions are issues throughout the universe. These issues have implications for public health. Particulate matter, sulphur dioxides (SOx), nitrogen oxides (NOx) and ozone (O_3) are some of the air pollutants (Nielson, 2013). The contributing factors of airborne pollutants in different cities of the world are the burning of fossil fuels, vehicular movements, high population increase, Coal-fired power plants, rapid economic growth, and others (Nielson, 2013; Abulude et al., 2018).

Carbon monoxide (CO)

The combustion of fossil fuels results in the emission of a variety of pollutants into the air. CO is one of the major ones present. The main sources of CO in the urban air are smoke and exhaust fumes of many devices, burning coal, gas or oil. The sculptures exclusively near the location of sources have detrimental effects like fading, breakage, corrosion, burns and the like (Nielson, 2013).

Nitrogen dioxide (NO_2)

This contributes a significant amount of the total loading of air pollution and acid rain. The biological sources of nitrate complicate the relation between atmospheric NOx levels and the occurrence of nitrates on exposed stone surfaces. The problem in finding calcium nitrate crystals on exposed stone surfaces is probably due to its very high solubility in water and its hygroscopic nature (Alghazawi, 2015). NO_2 drastically increases the corrosion rate of calcareous stones in SO-containing atmospheres at high (90%), but not at low (50%) relative humidity. Nitrate enrichment on different calcareous stone types is mainly from deposition of gaseous HNO and to a lesser extent, to dry deposition of NO. Microcracks in the stone structure caused by crystallization, and hydration, nitrates at ambient conditions may cause deterioration (Van, Grieken, 2010).

Hydrocarbons (HCs)

Hydrocarbons are present in coal, oil, and natural gas if these fuels are burnt carbon dioxide (CO_2) gas are when this gas is produced in excess it becomes air pollution (Usentaeva, 2014). An example is Volatile Organic Compounds (VOCs).The occupational exposures to tetra methyl lead, benzene vapours can cause health effects. Formaldehyde can cause irritation if inhaled. Hydrocarbon is contributory factors for eye and respiratory irritation which are caused by photochemical smog. Also, NOx gases react to form smog, acid rain and to the formation of fine particles (PM) and ground-level ozone, all these have adverse effects on the materials used in the building or forming the sculptures (Van, Grieken, 2010).

Aldehydes

Aldehyde, ketone, and methane in engines have harmful effects on human health (irritation of eye, throat, nose, asthma, pulmonary function) and environment (Mathews, 2016). The pollutants add to global warming, which is a major concern worldwide (Kumar et al., 2011). It is useful in various ways: as a sterilizing agent and as a preservative in foods, cosmetics, pesticides, for biological specimens and for human remains. It is also added to adhesives, resins, and foams. It affects plants and wildlife in the environment. As a Volatile Organic Compound (VOC), aldehyde may be involved in the formation of ozone, which is harmful to crops and materials.

Table 1: Materials for making an outdoor sculpture

Object Materials	Deterioration	Primary Air Pollutants	Environmental Factors Accelerating Damage
Metals	Corrosion/tarnishing	Sulphur oxides and other acidic gases(Acid rain)	Water, oxygen, salts
Stone	Surface erosion, discoloration	Sulphur oxides and other acidic gases, particulates	Water, temperature fluctuations, salt, vibration, microorganisms, carbon
Paint	Surface erosion (peeling), discoloration,	Sulphur oxides, hydrogen sulphide, ozone, particulates.	Water, sunlight, microorganisms
Textile dyes and Pigments	Fading, color change	Nitrogen oxides, ozone	Sunlight
Textile	Weakened fibers, soiling	Sulphur oxides, nitrogen oxides, particulates	Water, sunlight, mechanical wear
Paper	Embrittlement	Sulphur oxides	Moisture, mechanical wear
Leather	Weakening, powdered surface	Sulphur oxides	Mechanical wear
Ceramics	Damaged surface	Acid gases	Moisture
Glass	Breakage	Acid rain, acid mist, sulphur oxides, nitrogen oxides	Cloudiness

According to International Agency for Research on Cancer formaldehyde, an aldehyde is a carcinogen (USEPA, 2014).

Smog

In 2015, over 2.5 million people were reported died in India due to pollution. According to the report, pollution has been responsible for more deaths than child malnutrition, road accidents, and alcohol. Also, responsible for three times as many deaths caused by AIDS, malaria, and tuberculosis combined. Air pollution causes death as a result of diseases from heart disease, stroke, lung cancer, and chronic obstructive pulmonary disease (Chopra, 2017). In Great smog of Delhi, there was an air pollution, which spiked far beyond acceptable levels, thereby causing the $PM_{2.5}$ to be 955 mg per cubic meter, more than 16 times the safe limits, likewise, PM_{10} was 1,333 mg per cubic meter as against the maximum limit of 100 (Chopra, 2017).

Ozone

Ozone is a very reactive substance. According to Rao et al. (2014), Ozone present in the lower layer of the atmosphere (Troposphere) is more dangerous than that present in the stratosphere. The Ozone present in the stratosphere prevents the passage of UV radiation onto the earth as it shows an adverse effect on sculptures (Rao et al., 2014).

Ozone is produced when the sunlight reacts with pollutants in the atmosphere (upper) and at the indoors by electric or light equipment (photocopy machines, printers, some air filtering equipment). When sulphur and nitrogen compounds combine with moisture and other contaminants in the air, sulfuric acid or nitric acid is produced. Then this acid becomes problematic thereby causing deterioration in a wide variety of items (sculpture inclusive). Objects in the vicinity react directly with ozone thereby causing deterioration on the said objects (Rao et al., 2014).

Sulphur dioxide

Sulphur dioxide (SO_2), and hydrogen sulphide (H_2S) are produced by burning fossil fuels, sulphur bearing coal, and other organic materials. SO_2 is the most notorious pollutant responsible for metallic corrosion. Corrosion of sculptures made of hard metals (steel) starts at an annual mean concentration of 0.02 ppm. Sulphuric acid mist in the air causes deterioration of marble sculptures (Rao et al., 2014).

Ethylene

This is one the groups of substances known as the volatile organic compounds (VOCs). It may occur from chemical facilities using it, released in vehicle exhaust fumes, from waste incineration plants, in cigarette smoke (in traces) and naturally from green plants, fruits and other living organisms (SEPA, 2016). The problem may set in if the air is inhaled, resulting in a headache, drowsiness, dizziness, nausea, weakness, and unconsciousness. Studies have shown that ethylene is metabolized to ethylene oxide, which has more adverse effects on human health (SEPA, 2016). The International Agency for Research on Cancer has designated oxide of ethylene (ethylene oxide) as a carcinogen. In Canada, ethene in the air are reported to be from the combustion of fossil fuels to the use of ethene in various industrial processes and exhumed from cars older than 1992 (CEPA, 2016).

Fig. 1: Pictures showing the effect of air pollution (acid rain) on sculptures

(a-This picture shows the Philadelphia Merchants' Exchange built in 1832. The sharp edges and carving details gradually become rounded due to the effect of acid rain, b-The photo depicts the Chicago Tribune Building, Chicago, Illinois. The portions of the limestone were darkened by acid rain, c-A marble baluster at the Organization of American States building, Washington, D.C. The gypsum alteration crusts have blackened, blistered, and spoiled as a result of air pollution and d-A marble column at the Merchants' Exchange in Philadelphia shows loss of material due to exposure to rain and blackening of the stone surface where the stone is sheltered from rain (Watson, 1997).

Particulate matter (PM)

Solids that are suspended in the air are referred to as Particulate pollutants. PM sources are either anthropogenic or non-anthropogenic, these could come from both outdoor and indoor sources. Pollution particles are mainly dirt, dust, mold, pollen, and skin cells, and a variety of other materials that are mixed with smaller amounts. Pollutants diameter is in microns (1/1,000,000 of a meter). Knowledge of particulate size is important when one is working on the size of air filters in a building (Rao et al., 2014).

Some particles like pollen, mold and skin cells can be attractive to pests. When this happens deterioration occurs. Particulates are particularly dangerous when they attract moisture and gaseous pollutants. When PM interacts with gaseous pollutants, deterioration can occur as a result of the followings:

- When sulphates and nitrates come in contact with moisture, they become acidic.
- When it acts as a catalyst for the chemical formation of acids from gases
- When it becomes an attractant for moisture and gaseous pollutants

CAUSES OF AIR POLLUTION DAMAGE

Traffic

The congestion of traffic on the roads increases vehicle emissions, which degrade ambient air quality. This vehicle

emission has resulted in morbidity and mortality of drivers, commuters, and individuals habiting besides major roadways (Hsermes, 2012). The pollutant emitted by petrol, diesel, and alternative-fuel engines are CO, NOx, un-burnt HCs and PM. Vehicle pollutants cause immediate and long-term effects on the environment, for example, car exhausts emit a wide range of gases and solid matter, which cause global warming, acid rain, and which in turn harm the environment, human health, and materials (sculptures inclusive) (Green, 2018). Results from a research showed that health risks from traffic congestion are significant, and additional traffic can significantly increase risks, depending on the type of road and other factors (Zhang and Batterman, 2013).

Fig. 2: Tennessee marble lion sculptures (CSI, 2017a)

Industrial plants

The presence of chemicals, particulates or biological compounds in the atmosphere can harm human and animal health and damage the environment. Factories and other industrial installations have caused such pollution since the dawn of the industrial age by burning fuels, carrying out chemical processes and releasing dust and other particulates. Air pollution can be controlled through the installation of filters and scrubbers to clean exhaust fumes from factory processes, and by taking steps to minimize the generation of pollution at the source (Zhang and Batterman, 2013).

Natural disaster

Hurricanes, tornadoes, wildfires, storms, drought, floods, earthquakes, and volcanoes are examples of a natural disaster. There are three main causes of natural disasters (movement of the Earth, the weather, and extreme condition). It is difficult to predict these natural disasters, they can occur suddenly. Tropical storms are caused by hurricanes, when there is too much water in any water source, a flood occurs, and earthquakes can happen when the Earth's plates shift or jam above or underneath each other. These events cause loss to man, animals, and materials (sculptures are not speared) (Watson, 1997).

Fig. 3: Hall on Columbia University's Morningside Heights Campus in New York City (CSI, 2017b).

Agricultural activities

There are four main agricultural activities (soil management, enteric fermentation, manure management and fossil fuel consumption) according to the USEPA (2014). These are linked to the production of greenhouse gases. Agricultural activities like the use of insecticides, herbicides, and fungicides may end up causing air pollution. When fossil fuels are burnt, the gasses are released into the air which, in turn, causes air and water pollution. If the gases (carbon monoxide, nitrogen oxides, sulfur oxides and hydrocarbons) are released into the air, they become carcinogen and, form acid rain when mixed with rain. The USEPA reported that agricultural activities accounted for about 12 % of emission the US in 2012 (USEPA, 2014).

Burning of biomass

The burningof biomass (crop stubble, forest residues, and vegetation) is the combustion of organic matter in natural or man-made fires. Biomass burning is one of the sources of many PM and trace gases that increase the concentration of ozone at ground level. The smoke from the burning is composed of CO_2, H_2O vapour, CO, particles, HCs, NO_2 and many other compounds. The type of wood and vegetation being burnt, the temperature of the fire and the wind conditions dictate the type of smoke. Burning of biomass is rampant in Africa, Asia and elsewhere in the world (Chen et al., 2017). Efforts are being made throughout the world to reduce the burning of biomass.

FACTORS AFFECTING POLLUTION DAMAGE

Relative humidity (RH)

RH is a relationship between the volume of air and the amount of water vapor it holds at a given temperature. In RH, water plays an important role in various chemical and

physical forms of deterioration. There are many sources of excess water in the vicinities of sculptures. Examples are wet mopping, rain, flooding, leaking pipes, broken gutters, exterior humidity levels, nearby bodies of water, wet ground, moisture in walls, human respiration and perspiration, and evaporation.

The absorbance and giving off of water by organic materials and some inorganic materials depends on the RH of the surrounding air. Sculpture made of metals will corrode faster at higher relative humidity than other objects. There are the swelling and warping of wood and ivory, sculptures made of paper may cockle, or buckle; stretched canvas paintings may become too slack, and there could be mold growth. At higher RH, pests are more active. It is important to note that the temperature of the air determines how much moisture the air can hold. Warmer air can hold more water vapor. At low levels of RH, sculptures tend to shrink, discolour, stiffen, crack, disintegrates, and a flake off (Green, 2018).

Temperature

Temperature is the measure of the movement of molecules in an object. Molecules are the basic building blocks of all things. As the temperature increases, there is an increase in the speed of molecules in an object, they move faster and spread out; the object then expands. When it is another way round i.e, the temperature reduces, molecules slow down and come closer together; material, then contracts. Temperature and temperature variations can directly affect the preservation of sculptures in many ways. For example, at higher temperatures, chemical reactions increase, thereby causing deterioration by discolouration or disintegration of sculptures. If this deterioration is not detected, it can lead to a fire. Insects may eat more and breed faster, and mold will grow faster within certain temperature ranges. At high temperatures, sculptures can soften. Wax on sculptures may sag or collect dust more easily. At low temperatures, sculptures can cause desiccation which may eventually result in fractures of paints. Fluctuation in temperatures can cause sculptures to expand and contract rapidly. Temperature is a primary factor in determining RH levels. As temperature varies, RH also varies (Livingston, 2016; Abulude et al., 2017).

Radiation

Ultraviolet and visible light is radiation that disintegrates, fades, darkens, and/or yellows the outer layer of organic materials and some colored inorganic materials - unnecessary visible light that fades or darkens the outer layer of paints and wood (Livingston, 2016).

Contaminants

Another factor that affects air pollution is contaminants. These include gases (H_2S, NO_2, SO_2, and O_3; O), liquids (plasticizers that ooze from adhesives, grease from human hands), and solids (dust that can abrade surfaces, salt that corrodes metals). Contaminants disfigure sculptures, making them unpleasant to see, making them an eye saw within the vicinity of erection or placement (Abulude et al., 2017; Green, 2018).

Light

Light is a form of energy that stimulates our sense of vision. It is a factor of deterioration. The unit of measurement is the nanometer (1 nanometer (nm) equals 1 thousand millionth of a meter). It can cause damage to the sculpture. It causes fading, darkening, yellowing, embrittlement, stiffening, and a host of other chemical and physical changes. Sculptures made of these materials book covers, inks, feathers, furs, leather and skins, paper, photographs, textiles, watercolors, and wooden are sensitive to light. All types of lights emit varying degrees of UV radiation. This radiation (which has the most energy) is the most damaging to sculptures (Livingston, 2016).

Deterioration to sculpture caused by air pollution

According to Smithsonian American Art Museum (2015), outdoor sculpture is traditionally made of stone and metals (Table 1). The most vulnerable materials in sculpture making are marble and limestone to acid rain (Steiger, 2015). Other types of materials like granite and sand stone are resistant to acid attack. Cast iron, steel, zinc and lead, and bronze have also been used in sculpture. In a review by Tidblad (2015), bronze (Cu-Zn-Sn-Pb) has been preferred for sculpture since ancient times because of its resistance to corrosion and favorable casting properties. Pure copper is too soft for practical applications (Livingston, 2016). Other elements have usually been added to harden it and to change its colour. In antiquity, tin was the major alloying element, despite its high cost. Small amounts of lead improve the flowability of the molten bronze and enhance its ability to reproduce fine details.

In affirmation to the deleterious effects, air pollution has on sculptures, the pictures in Fig1 show why it is good to prevent or reduce the effects of air pollution.

Cases of sculpture damages and maintenances

The cases in this paper are taken from the project overview of Conservation Solutions Inc, Canada (CSI). They depict the steps, maintenance and major restorations needed for sculptures.

NEW YORK

Tennessee marble lion sculptures

The maintenance work on the sculpture was undertaken by CSI. The project was to remove iron stains left behind on the stone by holiday wreaths. The works were limited to a light general cleaning and stain removal on the sculptures (CSI, 2017a). Other, includes removal of atmospheric soiling, biological growth, gypsum crusts, and iron stains. Cracks and losses in were filled with injection grout and color matched patching mortar (Fig. 2).

Fig. 6: The Flagler Memorial Monument in Biscayne Bay (CSI, 2017e).

Fig. 7: Lead Sculptures Conservation - Vizcaya Museum and Gardens (CSI, 2017f)

Columbia University's Morningside heights campus

The bronze sculpture was worked upon to improve the dark coloration of the statue, obscuring its natural patina (Fig. 3). This maintenance work was performed by removing the existing wax coating. The bronze sculpture was spot-patinated to reduce the contrast between the areas of light green and black corrosion. The maintenance work was performed to increase the longevity of the sculptural treatment and to help reduce future deterioration (CSI, 2017b).

Metropolitan museum of art's American Wing courtyard

The reinstallation was performed on the pulpit salvaged from All Angel's Church (Fig.4). The reinstallation was based on the careful removal of each surrounding mortar joints by hand sawing. Care was taken to ensure no other damage. The element was carefully replaced in its original position and orientation. At the end of the exercise, newly carved limestone replacement blocks were integrated into the installation (CSI, 2017c).

FLORIDA

Fernando Botero's three Bronze sculptures

The three bronze sculptures are located at the Museum of Fine Arts in Saint Petersburg, Florida (Fig 5). The sculptures lost some of its protective wax coatings and also suffered damages to the foundry applied patinas due to the exposure to sun and wear. The salvage to the bronze was done by cleaning using anionic detergents and water, waxed, dried, heated with propane torches, re-waxed, and protected with corrosion inhibitors (CSI, 2017d).

Flagler memorial monument

This monument is sited on a man-made island in Biscayne Bay, between Miami Beach and Miami (Fig 6). The monument was damaged by vandalism and corrosion of the internal reinforcing. Surface erosion deteriorated the legibility of the forms. The solutions to these problems were provided by CSI. The entire monument was cleaned, loose and flaking paint and previous repair pargeswere removed, damaged concrete blast-cleaned, treated with a corrosion inhibitor and a protective coating, and rebuilt using restoration mortars. Cracks were injected with a compatible grout, and the entire structure was then coated with a potassium silicate paint matching the historic color (CSI, 2017e).

Lead sculptures conservation

The outdoor sculpture collection of Vizcaya Museum and Gardens in Miami, Florida (Fig 7) was preserved due to its vulnerability to damage due to air pollution. The lead sculptures became distorted, sagged and deformed under its weight. The CSI (CSI, 2017f), corrected and repaired the sculptures. The following steps were adopted: the surface accumulations, concrete, fiberglass, and synthetic resins were removed. Internal armatures were used to support the weight of each statue, cracks and previous losses were filled, and a patina was chemically developed on the surface, and they were re-installed in their original locations.

Steps to minimize the effects of air pollution on sculpture

Fig. 4: Karl Bitter's All Angels' Church Pulpit and Choir Rail (CSI, 2017c).

Fig. 5: Bronze sculptures by at the Museum of Fine Arts in Saint Petersburg, Florida Source: (CSI, 2017d).

1. Washing with detergents (anionic) and water
2. Waxing and Rewaxing
3. Application of corrosion inhibitors
4. Cracks and losses should be filled with injection grout and color matched patching mortar.
5. Painting (suitable paints - potassium silicate).
6. Heating, Ventilation, and Air Conditioning
7. Understanding the Effects of Different Temperature and Humidity Levels
8. Adequate use of monitoring equipment (Chicora Foundation, 1994).

Previous findings also revealed that the atmospheric deposition is damaging the monumental sculpture, which (Baker and Jickells, 2017; Chen et al., 2017; Corella et al., 2017; Feng et al., 2017; Krmar et al., 2017; Liang et al., 2017; Nanus et al., 2017; Omrani et al., 2017; Risch et al., 2017; Shelley et al., 2017; Tian et al., 2017; Yu et al., 2017), which need to bee protected from damage and loss due to atmospheric deposition.

CONCLUSIONS

Sculptures are used to describe large works, which are known as monumental sculpture. They are made of different materials like wood, stone, metal, and others. From this review paper, it could be noted that sculptures are adversely affected by air pollutants (PM, gases, and metals). The metals can corrode, the stone can deteriorate, dyes can fade quickly, polymers can breakdown rapidly, and paints can weather faster. In the long run, the sculpture may be defaced or damaged which eventually results in a loss. Steps to minimize the effect could be air conditioning, washing and rewaxing, painting, and the application of corrosion inhibitors just to mention a few. It is recommended that constant monitoring of atmospheric deposition should be ensured so the sculptures can be protected from damage or eventual loss.

REFERENCES

Abulude, F.O., Ndamitso, M.M., Abdulkadir, A. 2018. Environmental S ituation of an Agricultural Area in Akure, Nigeria, Based on Physico-Chemical Properties of Rainwater. Pollution, 4(2), 317-325.

Abulude, F.O., Ogunmola, D.N., Alabi, M.M., Abdulrasheed, Y. 2017. Museums and Monuments in Nigeria: Reducing Pollution Damage. Continental Journal Applied Sciences 12 (3), 42 – 56.

Alghazawi, R. 2015. Influence of Air Pollution on the Deterioration of Monuments and Museum Collections. Journal of Environmental Science and Engineering A, 4, 329-335.

Baker, A.R., Jickells, T.D., 2017. Atmospheric deposition of soluble trace elements along the Atlantic Meridional Transect (AMT). Progress in Oceanography 158, 41-51.

Canadian Environmental Protection Act (CEPA). 2016. Screening Assessment Ethene (Ethylene). Chemical Abstracts Service Registry Number (CAS RN) 74-85-1. Environment and Climate Change, Canada, Health Canada.

Chen, C., Li, J., Wang, G., Shi, M., 2017. Accounting for the effect of temperature in clarifying the response of foliar nitrogen isotope ratios to atmospheric nitrogen deposition. Science of the Total Environment 609, 1295-1302.

Chen, J., Li, C., Milic, A., Gu, Y., Islam, M.S., Wang, S., Hao, J., Zhang, H., He, C., Guo, H., Fu, H., Miljevic, B., Morawska, L., Thai, P. 2017. A review of biomass burning: Emissions and impacts on air quality, health, and climate in China. Science of The Total Environment, 579, 1000-1034.

Chicora Foundation. 1994. Managing the Museum Environment. http://cool.conservation-us.org/byorg/chicora/chicenv.html. Chicora Foundation, Inc. Retrieved: Monday, 04-Dec-2017

Chopra, K. 2017. Air Pollution in Delhi. Art and Activism. file:///C:/Users/USER/Desktop/Air%20Pollution%20and%20museum/Sculpture/Air%20Pollution%20in%20Delhi%20%E2%80%93%20ART%20AND%20ACTIVISM.htm.Uploaded December 11th, 2017.

Chris, P.N., 2013. Clearer Skies Over China: Reconciling Air Quality, Climate, and Economic Goals (Cambridge Mass.; London: The MIT Press), 7.

Corella, J.P., Valero-Garcés, B.L., Wang, F., Martínez-Cortizas, A., Cuevas, C.A., Saiz-Lopez, A., 2017. 700 years reconstruction of mercury and lead atmospheric deposition in the Pyrenees (NE Spain). Atmospheric Environment 155, 97-107.

CSI., 2017a. Cast Stone Obelisk Assessment and Conservation-Flagler Memorial Monument. Project Overview. Conservation Solutions, Inc.

CSI., 2017b. Fernando Botero's Three Bronze Sculptures Maintenance - Saint Petersburg Museum of Art. Project Overview. Conservation Solutions, Inc.

CSI., 2017c. Edward Potter's Marble Lions Maintenance - New York Public Library. Project Overview. Conservation Solutions, Inc.

CSI., 2017d. Lead Sculptures Conservation - Vizcaya Museum and Gardens. Project Overview. Conservation Solutions, Inc.

CSI., 2017e. Auguste Rodin's The Thinker Sculpture Conservation - Columbia University. Project Overview. Conservation Solutions, Inc.

CSI., 2017f. Lead Sculptures Conservation - Vizcaya Museum and Gardens. Project Overview. Conservation Solutions, Inc.

Feng, D., Liu, Y., Gao, Y., Zhou, J., Zheng, L., Qiao, G., Ma, L., Lin, Z., Grathwohl, P., 2017. Atmospheric bulk deposition of polycyclic aromatic hydrocarbons in Shanghai: Temporal and spatial variation, and global comparison. Environmental Pollution 230, 639-647.

Green, J., 2018. Effects of Car Pollutants on the Environment. Sciencing. Leaf Group Ltd.

Hermes, J., 2012. How Traffic Jams Affect Air Quality. Environmental Leader Inc.

Howard-McGuire, D. 2013. Air Pollution in Chinese Cities. Smog in Shanghai, China on November 7, 2013. ChinaFotoPress/ChinaFotoPress via Getty Images).

Krmar, M., Radnović, D., Hansman, J., Repić, P., 2017. Influence of broadleaf forest vegetation on atmospheric deposition of airborne radionuclides. Journal of environmental radioactivity 177, 32-36.

Kumar, S., Nayek, M., Kumar, A., Tandon, A., Mondal, P., Bhangale, U.D., Tyagi, D. 2011. Aldehyde, Ketone and Methane Emissions from Motor Vehicle Exhaust: A Critical Review. American Chemical Science Journal 1(1), 1-27.

Liang, J., Feng, C., Zeng, G., Zhong, M., Gao, X., Li, X., He, X., Li, X., Fang, Y., Mo, D., 2017. Atmospheric deposition of mercury and cadmium impacts on topsoil in a typical coal mine city, Lianyuan, China. Chemosphere 189, 198-205.

Livingston, R. A. 2016. Acid rain attack on outdoor sculpture in perspective. Atmospheric Environment, 146, 332-345.

Mathews, P. 2016. What are the effects of aldehydes and ketones in the atmospheric air? Quora

Nanus, L., McMurray, J.A., Clow, D.W., Saros, J.E., Blett, T., Gurdak, J.J., 2017. Spatial variation of atmospheric nitrogen deposition and critical loads for aquatic ecosystems in the Greater Yellowstone Area. Environmental Pollution 223, 644-656.

NPS Museum Handbook, Part I. 1999. Chapter 4: Museum Collections Environment. 4:1 – 4:50.

Omrani, M., Ruban, V., Ruban, G., Lamprea, K., 2017. Assessment of atmospheric trace metal deposition in urban environments using direct and indirect measurement methodology and contributions from wet and dry depositions. Atmospheric Environment 168, 101-111.

Rao, N.V.; Rajasekhar, M.; Rao, G. C. 2014. The detrimental effect of Air pollution, Corrosion on Building Materials and Historical Structures. American Journal of Engineering, 3 (3), 359-364.

Risch, M.R., DeWild, J.F., Gay, D.A., Zhang, L., Boyer, E.W., Krabbenhoft, D.P., 2017. Atmospheric mercury deposition to forests in the eastern USA. Environmental Pollution 228, 8-18.

Scottish Environmental Protection Agency (SEPA), 2016. Formaldehyde. Scottish Pollutant Release Inventory.

Shelley, R.U., Roca-Martí, M., Castrillejo, M., Sanial, V., Masqué, P., Landing, W.M., van Beek, P., Planquette, H., Sarthou, G., 2017. Quantification of trace element atmospheric deposition fluxes to the Atlantic Ocean (>40°N; GEOVIDE, GEOTRACES GA01) during spring 2014. Deep Sea Research Part I: Oceanographic Research Papers 119, 34-49.

Smithsonian American Art Museum. 2015. Smithsonian American Art Museum. Save Outdoor Sculpture Database.http://americanart.si.edu/research/programs/sos/.

Steiger, M., 2015. Air pollution damage to stone. P. Brimblecombe (Ed.), Urban Pollution and Changes to Materials and Building Surfaces, Imperial College Press (2015), pp. 65-102.

Tian, M., Yang, F., Chen, S., Wang, H., Chen, Y., Zhang, L., Zhang, L., Xiang, L., Qiao, B., 2017. Atmospheric deposition of polycyclic aromatic compounds and associated sources in an urban and a rural area of Chongqing, China. Chemosphere 187, 78-87.

Tidblad, J., 2015. Air pollution damage to metals. P. Brimblecombe (Ed.), Urban Pollution and Changes to Materials and Building Surfaces, Imperial College Press, 143-164.

US Environmental Protection Agency (USEPA). 2014. Trends in Greenhouse Gas Emissions." Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012 – Trends. EPA.gov. Environmental Protection Agency, Mar. 2014. Web. 5 Aug. 2014.

Usentaeva, A., 2014. Natural Source of Hydrocarbons. Prezi Inc.

Van, Grieken, R., 2010. Identifying the Sources of Atmospheric Particles in Museum Environment. In COST D42 WG2 Meeting, 65-72.

Watson, J., 1997. How does acid precipitation affect marble and limestone buildings? https://pubs.usgs.gov/gip/acidrain/5.html.

Yu, H., He, N., Wang, Q., Zhu, J., Gao, Y., Zhang, Y., Jia, Y., Yu, G., 2017. Development of atmospheric acid deposition in China from the 1990s to the 2010s. Environmental Pollution 231, 182-190.

Zhang, K., Batterman, S., 2013. Air pollution and health risks due to vehicle traffic. Science of the Total Environment. 15, 307–316.