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"Influences of atmospheric corrosion caused by air pollutants on materials and properties"

Mukhtar Shaglouf, Faraj Al-Tahar, Sana Ibrahim and Abubaker K. Elayatt

Chemical Engineering Department
Faculty of Engineering
The University of Sirte
P.O. Box 674 Sirte - Libya

Abstract: Corrosion problems remain the main hazard to the environment and atmospheric corrosion is probably the most common form of corrosion that causes these problems. Emissions of pollutants cause serious corrosion impacts on materials and buildings in the developing countries. Emissions of pollutants can cause serious corrosion impacts on buildings in most urban areas. This study essentially deals with atmospheric corrosion to assess the degrading effects of air pollution on various metals that commonly used in engineering systems. Galvanized iron, mild steel, stainless steel, copper, aluminum and brass are common examples of these engineering materials. In addition to air pollutants, environmental impact and air pollution from ships have received increasing attention recently. In order to assess these influences caused by ship emissions, some information on ships' activities and fuel used is necessary. The aim of this work is to survey and compare the corrosion effects on some engineering materials and buildings.

Keywords: atmospheric corrosion, air pollution, ships, materials, buildings.

1. Introduction

The term "atmospheric corrosion" comprises the attack on metal exposed to the air as opposed to metal immersed in a liquid. Atmospheric corrosion is the most prevalent type of corrosion for common metals [1]. The emission of air pollutants into the air takes place from different sources such as vehicles, engines, power plants, smelters, industrial boilers, petroleum refineries, and manufacturing facilities as well as from area and mobile sources. Primary pollutants are those that are emitted directly into the air from pollution sources. Secondary pollutants are formed when primary pollutants undergo chemical changes in the atmosphere. Ozone (O_3) is an example of a secondary pollutant. It is formed when nitrogen oxides (NO_x) and volatile organic compounds (VOCs) are mixed and warmed by sunlight. The above mentioned pollutants are corrosive to various materials which cause damage to cultural resources. The degradation of material exposed to the air and its pollutants usually represents atmospheric corrosion and considered to be the most common form of corrosion. In order to use metals in outdoor structures in proper ways, it is important to know the corrosion rates of these metals in different environmental applications. A common method for estimating the life of metals has been the use of various types of metals and alloys for the different types of atmospheres. Due to the differences in corrosivity, atmospheres are divided into rural, urban, industrial, marine, or a combination of these. The corrosion rates of various metals exposed to different atmospheres have been examined by many investigators [2-4]. In their study, Uhlig and Revie concluded that a metal that resists one atmosphere may lack effective resistance to other atmospheres, so the relative metals performance varies with location [5]. For example, galvanized iron performs better in rural atmospheres compared to that of industrial atmospheres.

2. Environments classifications

Environments (corrosive atmospheres) include saline, industrial, urban and rural. Saline atmosphere has high salt (NaCl) content. Industrial atmospheres are those in an area of heavy industries with soot, fly ash and sulfur compounds as the principal constituents such as NO_x, CO, CO_2, SO_2, SO_3. The gases resulted from industrial environments are generally considered the most aggressive in terms of corrosion. These gases cause lots of corrosion problems as they from mild acids with rain waters (acid rain).

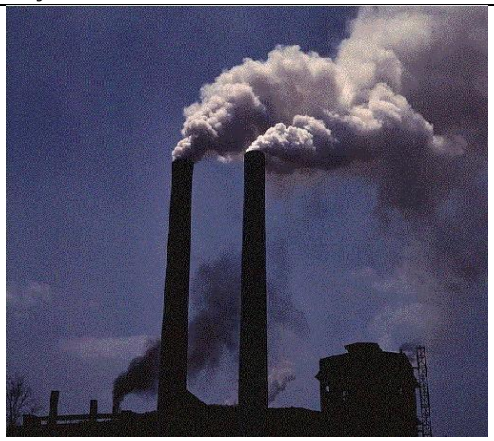

Figure 1: Air pollution from a fossil-fuel power station [6]

Urban atmospheres (cities) are the source of numerous dangerous gases, particularly vehicles (cars, Lorries, buses, etc.), airplanes and ships, which produce exhaust gases of fuel combustion. The produced gases from urban atmospheres include; carbon dioxide (CO_2), carbon monoxide (CO), Sulphur dioxide (SO_2), nitrous oxides (NOx) and ozone (O_3). Finally, even though the rural atmosphere is considered almost pollution free, still has some organics gases such as methane, ethane and (hydrogen sulfide) H_2S due to untreated sewage and waste water.

3. Pollutants emitted by ships

Shipping has an essential role in the global transport system. One estimate claims that the shipping industry carries more than 80% of the total volume of transported goods in the world [7]. The amount of goods in sea borne trade has grown throughout the last century, and from 1970 to 2008 the increase was more than threefold. Also, the average ship size has increased; the average age of a ship was 23 years in 2009 while the average age of a dead weight ton (DWT) of the same fleet was 14 years [8]. Pollutants formed from fuel combustion can be classified as either primary or secondary pollutants. Primary pollutants are those formed during the actual combustion process, while secondary pollutants are resulted from chemical reactions involving the primary species. One of the potential impact types influenced by air pollution from oil combustion is atmospheric corrosion. The increase of transport activities has increased the emission of CO_2 from ships. Also minor amounts of methane (CH_4) and nitrous oxide (N_2O) are emitted from ships as well [9].

4. Effect of pollutants on atmospheric corrosion

Atmospheric corrosion is probably the most common form of corrosion and is defined as the corrosion or degradation of materials exposed to air and its pollutants. In addition to parameters such as temperature, relative humidity and precipitation, microbiological activity can also be of great importance that governs atmospheric corrosion [10].
It is useful to subdivide the effects of pollutants into wet and dry deposition. Wet deposition represents the transport of pollutants by means of precipitation in the atmosphere. Dry deposition includes the pollutants transport by any other processes and is usually dominating close to the pollution sources in urban and industrial locations.

5. Structures damages caused by atmospheric corrosion

Usually stone cultural properties everywhere are made of (marble, limestone and sandstone). So these materials are greatly affected by acid rain and atmospheric pollution. These pollutants dissolve the surface of the stone objects, subsequently reduce their values and in many cases can cause the demolition of them.

Figure 2 Building damages caused by acid rain, Copola, Mexico [11].

Gold, silver, copper, bronze, iron and lead are examples of metals cultural properties. When bronze is left outdoors for long periods of time, a fine dark layer of rust composed of basic copper carbonate gradually forms on the surface [12].
In the case of durable bronze, pollutants resulted from acid rain dissolve or break up the copper carbonate film on the surface, consequently the bronze object becomes susceptible to corrosion by copper sulfate and basic copper chloride. As a result, the surface color changes to a vivid yellow-green and corrosion and deterioration are accelerated. Table 1 below summarizes the influences of air pollutants on different cultural structures.

Table 1. Cultural properties affected by atmospheric pollution [12]

Types of Cultural properties	Pollutants	Effects
Metals	Acid rain, SOx, NOx, Cl	Corrosion, discoloration etc.
Stones	Acid mist, SOx, NOx, Cl	discoloration, deterioration
Wooden	Acid rain, SOx, NOx, Cl	deterioration discoloration
Wall paintings	Acid mist, SOx, NOx, Cl	peeling, discoloration
Glass	Acid rain, SOx, NOx, Cl	cloudiness
Oil paintings	Ammonia	deterioration of oils, cloudiness of varnish

A fishermen harbor, which was built in Sirte city (Libya) about 30 years ago, is affected by pollutants from the sea. Figure 3 illustrates the corrosion damages that caused by saline environment.

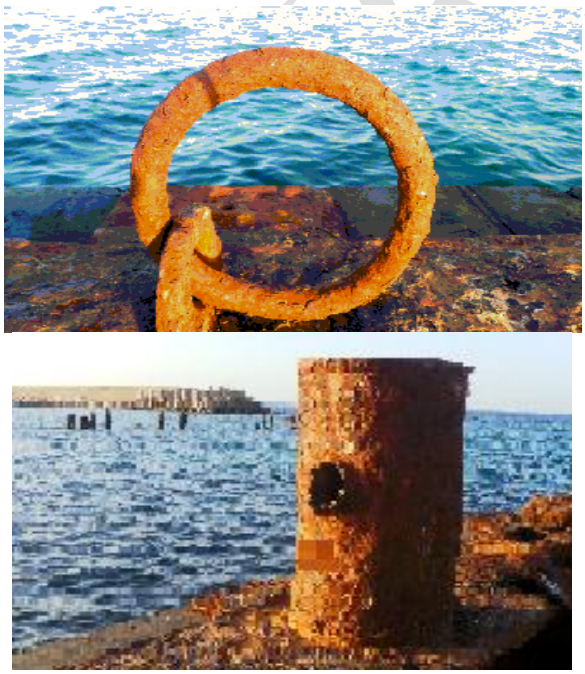

Figure 3: Sirte fishermen harbor corrosion damages

Conclusion

All of the above mentioned corrosive environments cause corrosion of metals and alloys and subsequently influence engineering materials and buildings. While most developed countries have put in measures to reduce vehicle emissions, in terms of fuel quality and vehicle emission reduction technologies, these measures are yet to be adopted in most cities in developing countries. The effects of atmospheric pollution build up year after year, and they cause damages to all cultural properties, whether they are in cities or in a rich natural environment, whether they are indoors or outdoors, and regardless of the materials from which they are made. Atmospheric pollution causes cultural properties to deteriorate at a rate up to several hundred times the speed of natural deterioration. Moreover cultural properties that have been carefully taken care of for a very long time can be destroyed in a shorter period of time that results in a major crisis. Various methods of prevention can be considered for the protection of cultural properties from atmospheric pollution. However, together with the application of preservation methods, studies must be performed about the surrounding environments of those cultural properties. Also environmental standards should be established as well. Finally it is necessary to understand that protecting cultural properties and save them for the new future generations needs big efforts and hard research work.

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