Research Paper Environment

Corrosion Study of some Metals in an Urban Atmosphere

* V. Saritha

* Department of Environmental studies, GITAM Institute of Science, Visakhapatnam- 5300045, Andhra Pradesh, India

ABSTRACT

This study essentially deals with atmospheric corrosion of metals like Iron, Copper, Steel and Aluminium. Eight different locations based on various activities were selected. The results are discussed as functions of the type of location, test material, and exposure time. The results indicate that iron and copper were prone to elevated corrosion, while steel recorded medium level and aluminum the least corroded. Among the locations, Maddilapalem emerged as the site with the highest effect on metals in terms of corrosion. Furthermore, greater corrosion rates were observed in the Rushikonda area, close to the coast followed by Gajuwaka and Kancharapalem sites. The results of the study can be used to obtain a corrosion fingerprint of the locations included in the study. The study provides an insight into the pollution effects on metals and their location specific activities with reference to corrosion which can be applied for suggesting alternatives or control methods.

Keywords: Corrosion, Pollution, Metals

Introduction

Atmospheric corrosion is a process of practical importance because of its effects on structures, devices and products exposed to external environments (Costa & Vilarrasa, 1993). It is the most widespread form of metal deterioration that affects manmade metallic structures (Sawant & Wagh, 1991). The material damage caused by corrosion can be substantial and, in addition to direct metal losses, the damage is also associated with replacement or repair of products and objects, which increases the economic losses. Damage due to premature atmospheric destruction of historic and cultural monuments can hardly be estimated at all (Mikhailov et al. 1995).

Monitoring environmental pollution is normally performed by measuring the key gaseous pollutants and a number of climatic parameters (Johansson & Leygraf, 1999). However, it was found that the characteristics of the environment and its content of pollutants play an important role in understanding the corrosion rates of metals. Therefore, atmospheric pollution can be evaluated by determining the corrosion attack on samples of different metals exposed to the atmosphere. The analysis of exposed metal samples provides direct information on the corrosion processes. It has been shown that the corrosion process is mainly affected by exposure time; some climatic factors, including humidity, temperature, sulphur content, salinity; and the presence of some other pollutants (Costa & Vilarrasa, 1993).

Many investigators have examined the corrosion rates of various metals exposed to different atmospheres (Upham, 1967; Knotkova et al. 1995; Kucera & Fitz 1995; Mikhailov et al. 1995). A metal resisting one atmosphere may lack effective resistance in another; hence, the relative performance of metals changes with location. For example, galvanized iron performs well in rural atmospheres, but it is relatively less resistant to industrial atmospheres (Uhlig & Revie, 1985; Revie, 2000). Recognition of the marked differences in corrosivity has made it convenient to divide atmospheres into "types".

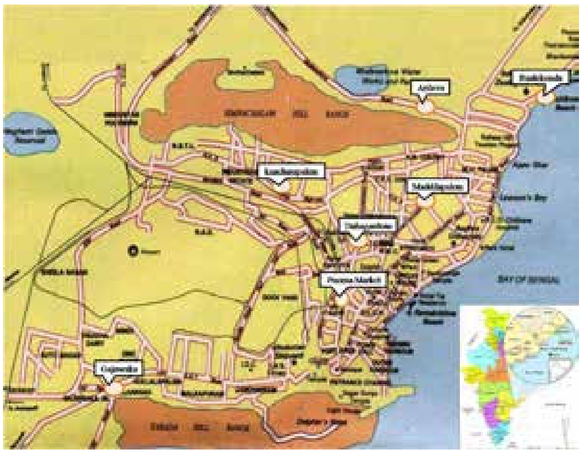
In this study, the atmospheric corrosion of common metals was studied at five locations of Visakhapatnam, selected based upon their type of activity / environmental condition. The areas were categorized as industrial zone, urban traffic zone, coastline zone and the heavy populated (floating) zone. The purpose of this work was to present the results of the 3 months exposure period, which extended from February, 2010 to April 2010. The focal idea of the present study is to assess the effect of pollution at various locations with respect to corrosion of the metals.

Materials and Methods

Study Area and Sampling Sites

Atmospheric exposure tests were conducted at five test sites in the City of Visakhapatnam. All sites are located within the city limits. These sites varied considerably with respect to moisture content, temperature and contaminants (e.g., dust content); therefore, they were divided into "types", i.e various categories as follows

"Figure – 1"



Sampling Site	Type
Rushikonda	Marine
Siripuram	Commercial
Dabagardens	Commercial
Gajuwaka	Industrial
Purna Market	Market
Maddilapalem	Heavy traffic zone
Kancharapalem	Heavy traffic zone
Aarilova	Residential (Control)

Preparation of Samples

For each metal type, flat specimens measuring 5x2 cm were sheared from sheets, which were obtained from the same batch to ensure similar composition. Specimens exposed in all the areas were orientated in such a way that they faced a major emission source. This convention was used because all the four exposure sites were close to source of pollutants such as sea spray, industrial stacks or ambient air pollution from vehicular sources (Abdul-Wahab et al. 2002).

Post Exposure Studies

Specimens were removed from each site after exposure periods varying from one to three months. Methods given by Sabah (2002) were used for the cleaning procedures required before exposure and for cleaning and evaluation after exposure.

The amount of metallic corrosion was determined by the weight-loss method, which involved cleaning and weighing each test specimen prior to exposure. After the exposure period, the product of corrosion from each specimen was carefully removed and the specimen was reweighed. The average weight loss per unit area provided a measure of the amount of metal lost by corrosion.

Results and Discussion

The environmental factors responsible for the corrosion of metals have been studied at various locations of Visakhapatnam City. The major types of sampling sites include rural, urban, industrial, marine, or a combination of these.

Table - 1 shows the relationship between the average corrosion weight-loss values of the exposed test metals and the corresponding test sites for each exposed metal. The corrosion weight-loss values give a direct measure of the corrosion attack. Steel and copper have undergone moderate corrosion but higher of loss of metal due to corrosion was observed in metals Ion and Aluminium.

Table – 1 Weights of the Metal Specimens at regular intervals of Atmospheric Exposure

Sample	15th Day	30th Day	45th Day	60th Day	75th Day	90th Day
Poorna Market						
Iron	1.755	1.725	1.710	1.684	1.676	1.655
Copper	4.545	4.512	4.504	4.494	4.490	4.488
Steel	5.000	4.990	4.983	4.979	4.972	4.968
Aluminum	2.800	2.787	2.781	2.774	2.768	2.763
Maddilapalem						
Iron	1.902	1.887	1.874	1.870	1.865	1.858
Copper	4.255	4.246	4.240	4.238	4.232	4.226
Steel	4.345	4.336	4.330	4.326	4.321	4.316
Aluminum	2.563	2.250	2.544	2.537	2.530	2.526
Kancharapalem						
Iron	1.835	1.827	1.818	1.812	1.811	1.798
Copper	4.523	4.512	4.506	4.500	4.496	4.491
Steel	4.945	4.940	4.937	4.932	4.929	4.926
Aluminum	2.722	2.713	2.710	2.706	2.702	2.696
Rushikonda						
Iron	1.931	1.923	1.917	1.914	1.910	1.906
Copper	4.167	4.150	4.142	4.134	4.126	4.118
Steel	4.450	4.442	4.438	4.436	4.425	4.420
Aluminum	2.584	2.576	2.570	2.566	2.562	2.558
Gajuwaka						
Iron	1.821	1.817	1.806	1.800	1.795	1.790
Copper	3.918	3.913	3.910	3.906	3.900	3.895
Steel	4.711	4.701	4.695	4.692	4.685	4.680
Aluminum	2.679	2.672	2.667	2.660	2.657	2.650
Dabagardens						
Iron	1.935	1.926	1.920	1.918	1.914	1.910
Copper	4.672	4.670	4.668	4.664	4.661	4.659
Steel	4.813	4.807	4.804	4.801	4.799	4.796
Aluminum	2.652	2.648	2.646	2.642	2.640	2.597
Siripuram						
Iron	1.787	1.781	1.776	1.770	1.768	1.764
Copper	4.160	4.154	4.150	4.148	4.144	4.140
Steel	4.807	4.801	4.798	4.795	4.790	4.786
Aluminum	2.650	2.643	2.638	2.632	2.630	2.626
Aarilova						
Iron	1.895	1.884	1.880	1.874	1.870	1.864
Copper	4.480	4.472	4.463	4.454	4.446	4.436
Steel	5.131	5.122	5.118	5.114	5.110	5.104
Aluminum	2.520	2.505	2.496	2.490	2.484	2.476

It was observed that steel and copper resisted corrosion under almost all atmospheric exposure conditions; hence, their corrosion rates were relatively low and in some areas (i.e., Siripuram), almost negligible. This indicates the suitability of these metals under the prevalent atmospheric conditions in these areas. In the case of copper, the severity of corrosion attack in the marine atmosphere (i.e., Rushikonda) was fairly less than that in the industrial atmosphere (i.e., Kancharapalem). The decrease in the corrosion rate was attributed to the attractive and protective patina of copper specimens that form during marine exposure. In marine atmospheric exposures, this patina consists of a film of basic copper chloride or carbonate, sometimes with an inner layer of Cu_2O.

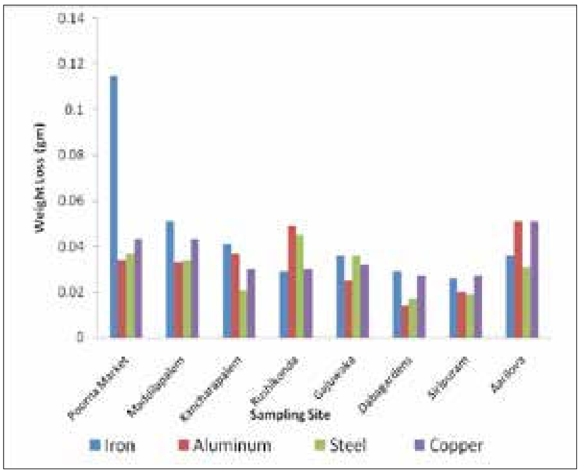
Table – 2 shows the relationship between the average corrosion weight losses corresponding to the exposure site (Fig – 1). The objective of this figure is to develop some corrosion profiles of the test sites, as the relative performance of metals changes with location. It is known that the most commonly used metal, Iron, is quite sensitive to atmospheric corrosion.

Therefore, it is a useful indicator of the effects of air pollutants on materials exposed to the atmosphere.

Table – 2 Weight Loss at the end of 90th Day in the exposed metals

Area / Metal Specimen	Iron	Aluminum	Steel	Copper
Poorna Market	0.115	0.034	0.037	0.043
Maddilapalem	0.051	0.033	0.034	0.043
Kancharapalem	0.041	0.037	0.021	0.030
Rushikonda	0.029	0.049	0.045	0.030
Gajuwaka	0.036	0.025	0.036	0.032
Dabagardens	0.029	0.014	0.017	0.027
Siripuram	0.026	0.020	0.019	0.027
Aarilova	0.036	0.051	0.031	0.051

Fig.1 Exposure Site wise Weight Loss in grams at the end of 90th Day



The effect of the test site is clear, that the corrosion attack of Iron is dependent on the environmental conditions of the area under test. The figure shows that the corrosion-weight loss values of the attacked Iron vary from one exposure site to another. The most corrosive site was Purna Market and the least corrosive site was Siripuram.

Another feature of interest is the variation in the corrosion weight loss values of steel. It was observed that the epoxy appearing on the surface of steel plays an important role in lowering the corrosion attack of steel. Accordingly, it may become economical to use epoxy for the protection of steel parts under conditions of high sulphur pollution (Sahab et al. 2002; Sahab, 2003). It has been shown that the corrosion process is mainly affected by exposure time; some climatic factors, including humidity, temperature, sulphur content, salinity; and the presence of some other pollutants (Costa & Vilarrasa, 1993).

Approaching the seacoast, air is laden with increasing amounts of sea salt, particularly NaCl. Also, specimens exposed to marine atmosphere corrode at greatly different rates depending on proximity to the ocean (Sawant & Wagh, 1991). In normal atmospheres containing pollutants, metals begin to corrode at this accelerated rate when the relative humidity of the air layer next to the surface exceeds about 75%, mostly in coastal areas where the main factor of corrosion is the presence of chloride ions (B.Boyle, 2004 and Roberge et.al., 2002).

Conclusion

In many situations, the structural components in outdoor environments are subjected to the cyclic effects of weather, geographical influences, and bacteriological factors that cannot be realistically duplicated in the laboratory. Therefore, outdoor exposure testing is important for objectives such as selecting a material, predicting the probable service life of a product or structure, evaluating new commercial alloys and processes, and calibrating laboratory corrosion tests (Revie, 2000).

In industrial areas, appreciable amounts of SO2, which converts to sulfuric acid, and amounts of H2S, NH3, NO2, O3 and various suspended salts are usually encountered (Uhlig & Revie 1985; Revie, 2000). Although the prediction of corrosivity is still not possible, it appears that humidity, temperature, and levels of chloride, sulphate, and probably other atmospheric pollutants present each exert an influence on the corrosion rate of metals (Revie, 2000).

The reason behind the corrosion of metals at high traffic zones can be attributed to the presence of sulfur dioxide (SO2), which is the gaseous product of the combustion of fuels that contain sulfur such as coal, diesel fuel, gasoline and natural gas. This has been identified as one of the most important air pollutants which contribute to the corrosion of metals. Less recognized as corrosion promoters, are the nitrogen oxides (NOx), which are also products of combustion. A major source of NOx in urban areas is the exhaust fumes from vehicles. Sulfur dioxide, NOx and airborne aerosol particles can react with moisture and UV light to form new chemicals that can be transported as aerosols. A good example of this is the summertime haze over many large cities. Up to 50% of this haze is a combination of sulfuric and nitric acids.

The results indicated the suitability of steel under all atmospheric conditions. In case of copper, it was found that the severity of corrosion attack in marine atmospheres is somewhat less than that in industrial atmosphere. In case of epoxy, it was found that it played an important role in lowering the corrosion attack of mild steel.

The geographical location of test sites indicated a clear relationship between chlorides and proximity to the coast. It was found that higher concentrations of chlorides were observed in the Rushikonda, which are close to the seacoast. Also, the highest carbonate sites were located in the Kancharapalem areas, which are the more polluted industrial areas. Moreover, it may be concluded that the atmosphere at Gajuwaka was polluted with sulphur compounds, which played an important role in enhancing the corrosion attack of the metals, particularly mild steel.

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