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Environmental Effects on Electronic Devices in Mexico

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Abstract

This paper shows the results of the assessment of impairment suffered by elements of electronic equipment by environmental effects in different climatic zones of Mexico. For this study, evaluated devices were evaluated that are mostly exposed under different climatic conditions of operation, to determine the degree of damage suffered which leads to malfunction, reduced service life and loss of information in some cases. The main contribution is to identify the causes of the deterioration to delay the effect of atmospheric corrosion deterioration in electronic components. The Mexican Republic has a wide range of climates and subclimates over its territory, sampling was performed for each one of the most representative regions, by their nature tend to be more conducive to the release of corrosive effect on the computer and electronic devices. For the determination of existing impairment in electronic equipment, a methodology is proposed for the evaluation of samples taken from each region, determining the degree of corrosion that exists in these devices. It should be noted that according to the literature, the main pollutants that lead to the deterioration caused by corrosive environmental phenomena are SO_2, NO_x, CO, CO_2, coupled with the presence of ozone and chloride, characteristic of the coastal region, combined with the percent relative humidity (% HR), and temperature cycles as reported by environmental monitoring systems in Mexico. With the study of atmospheric corrosivity in electronic devices has been determined: 1) Design and operation of chamber to accelerated atmospheric corrosion testing. 2) Identification of electronic components with increased susceptibility to corrosive phenomena under typical environmental different regions of Mexico. 3) Correlation of damage suffered in electronic equipment under typical operating conditions and accelerated tests. 4) Determining the degree of atmospheric corrosion on electronic equipment. 5) Construction of atmospheric corrosivity map for Mexico in electronic devices.

Keywords

Atmospheric Corrosion, Damage, Electronic Devices, Degree of Atmospheric Corrosion, Corrosivity Map

1. Introduction

Since the early 1960s, several authors [1] have found that electronic devices, electronic and magnetic induced failures can occur due to corrosion, with this phenomenon should guide the analysis according to the particular characteristics of the different elements considering the atmospheres under which the devices are in operation for more accurate analysis.

In more recent work [2] [3], these devices are classified according to their dimensions, characteristics and application as follows:

- Microelectronics (printed circuit boards, integrated circuits).
- Macroelectronics (switches, connectors, resistors, capacitors, batteries, etc.).
- Data storage magnetic devices (SAMD).

One aspect to consider in determining the correlation between the time anywhere in the world and the deterioration of electronic devices is the wide variety of climates and existing subclimates, as in the case of Mexico, due to its geographical extent (is located between latitude 14˚N to 33˚N and 86˚W to 119˚W), and the abundant presence of different gaseous pollutants (SO_2, O_3, CO_2, NO_x) [4] [5] characteristic of large cities and industrial mounted, significant elevations above sea level (e.g. Mexico City has it's the bigger city, with more than 20 million people at a height of 2240 m.a.s.l [6]), the existence in some areas of the pollutants characteristic of agricultural practices (grazing and burning of sugar cane crops [7]), or the presence of chlorides in the areas near the coast (Mexico has more than 10,000 miles of coastline), or a combination of the gases released by petrochemical processes, with a typical coastal salinity and high humidity and temperature (as in some industrial areas in the Gulf of Mexico).

As there is a high degree of variability in corrosivity of the environment favors the presence of corrosive phenomena in electronic devices, coupled with a situation that limited use of air conditioners, resulting in a more aggressive corrosion than those observed and studied in developed countries.

The purpose of the present study is to give guideline to the identification of the causes that lead to the damage by atmospheric corrosion in electronic devices, being a first stage where it is intended:

- Identification of electronic components with increased susceptibility to corrosive phenomena under typical environmental different regions of Mexico.
- Determining the degree of atmospheric corrosion on electronic equipment.
- Construction of atmospheric corrosivity map for the Mexican Republic in electronic devices.

2. Problematic in Electronic Devices

The drawbacks in the performance of electronic devices are produced due to the presence of precursors such as corrosion of condensate by the effect of operating conditions and the presence of high levels of (%RH). The solutions in these condensates of pollutants modify the pH of the solution. Moreover, the presence of particles also promotes decay processes promoting the formation of condensates, which also allow the generation of short-circuits, or to the existence of eddy currents.

The failures in the operation can also be correlated with design factors by failing to ensure hermeticity in devices that contain electronic cards, promoting with this filtration of dust, moisture and more atmospheric agents.

The materials used in electronic devices are several metals and alloys which by their nature are optimal for use as in the case of Cu, Al and its alloys. In the case of coatings are generally employed Sn, Au, Ni, Ag, Pd.

As regards metal parts that make up this type of device are protected against environmental effects usually with an organic coating or by passivation treatments. In the case of printed circuit contacts, connectors and switches, are exposed to environment, and are therefore highly prone to corrosion.

3. Development

In order to identify the root problem that leads to deterioration electronic devices have been classified into different types of faults:

- Electronic.
- Mechanical.
- Atmospheric corrosion.

By focusing this study in damage per environmental effects is proposed the following classification according to Table 1.

The integration of information necessary to identify areas with the highest atmospheric deterioration occurs in the collection of samples that have been withdrawn from service for any failure presented. According to data from weather monitoring stations in Mexico, the regions where the conditions are

Table 1. Characteristics of the representative atmospheres in Mexico, according to ISO 9223:2012 [8].

Atmosphere	Characteristics
Industrial	Emissions from heavy industry, concentrations of chloride, phosphate and nitrate and formation of sulfur dioxide from combustion.
Urban	The most common pollutants are NOx (NO + NO_2) and SO_X from combustion of fossil material and product of anthrononenic mobile sources.
Marine	Existence of high concentrations of chlorides with values above 15 mg/m^2-dia NaCl. The corrosivity can be strengthened by the existence of industries in the area, together with temperature, relalive humidity and wind direction.
Rural	It is the presence of pollutants from fertilizers, as well as decomposition of organic matter, result in a the presence of ammonium ions, nitrates.

conducive to a greater intensity in presence of atmospheric corrosion, considering the following parameters:

- Winds.
- Distribution of rainfall in the year.
- Mean annual temperature.
- Climatology of Mexico [6] [9].

In addition to the parameters established to date has a generalized classification of climates representative of existing regions in Mexico (**Figure 1**).

The sample (260 units) was performed in 16 states of Mexico (**Figure 2**) whose characteristics are due to the orography of the Mexican Republic, in terms of its climate and geographical location considering annual average temperatures, rainfall as well as mountainous regions such as the case of the northern region of the country.

4. Methodology

The methodology specifies the procedure for the inspection of specimens of the total sample (**Figure 3**), considering the analysis of field samples and samples that have not been used, and these, benchmarks for evaluation of damage by

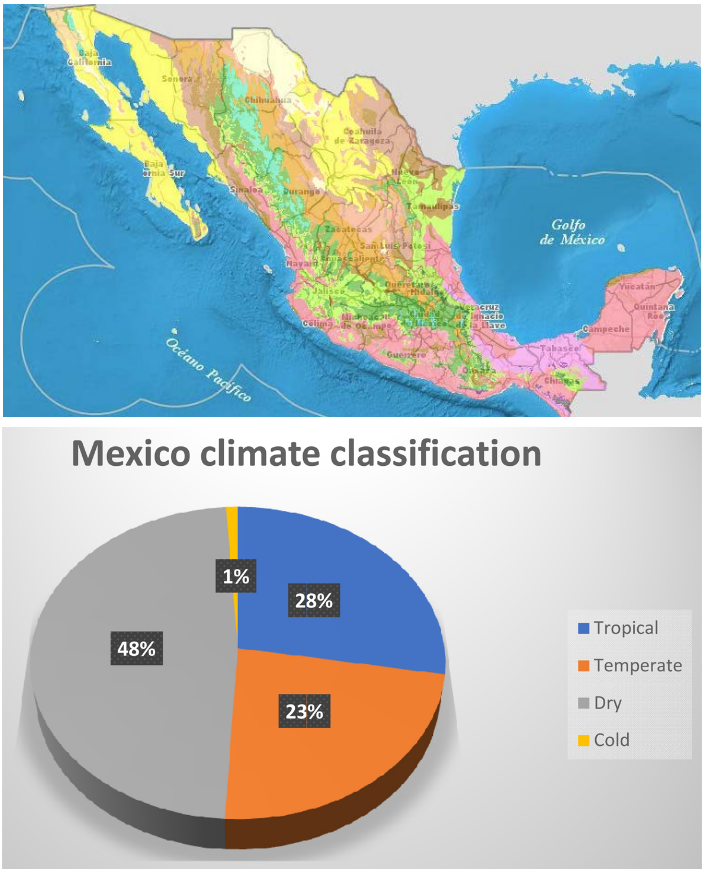


Figure 1. According to the existing climatology in Mexico, the most representative climate is dry with 48% followed by the Tropical (humid-subhumid-perhumid) with 28% of the country [10].

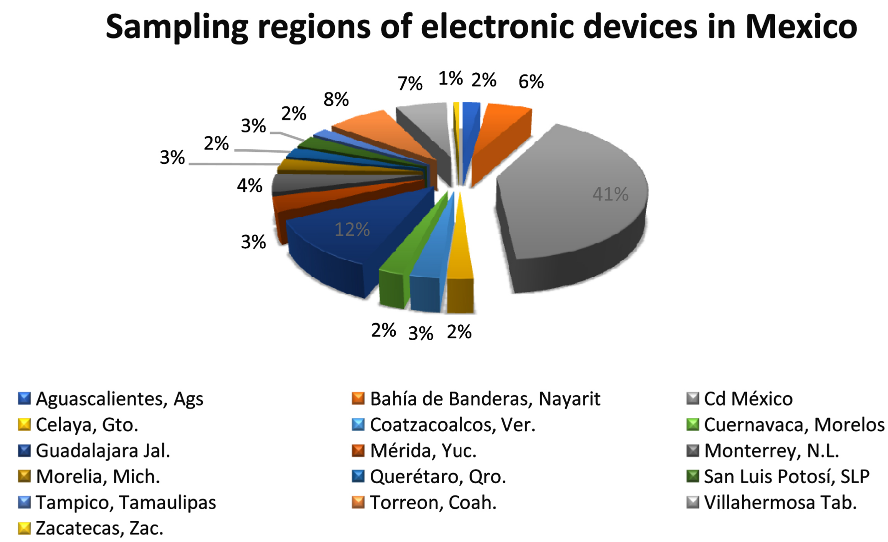


Figure 2. Regions evaluated in Mexico according to the percentage of specimens of electronic devices.

testing accelerated atmospheric corrosion simulation [11] [12] [13]. According to the Classification of outdoor environments for corrosion protection [14] [15], the following parameters are considered to determine the degree of corrosivity.

- T: time wetting
- P: Category pollution from sulfur components based on levels of SO_2 present in the atmosphere
- S: Category of pollution based on the Cl-existing levels in the atmosphere
- C: Atmospheric corrosivity category.

The maximum permitted levels of pollutants (**Table 2**) reported in the monitoring networks in Mexico [16], are considered as benchmarks for testing accelerated atmospheric corrosion in electronic devices.

5. Results of Damage Suffered in Electronic Devices

Considering the regions evaluated, both devices field and accelerated tests, it is determined that the elements suffer a greater deterioration with a high incidence are classified as micro-electronics.

Moreover, the atmosphere more conducive to their conditions for the presence of corrosion is the marine-industrial due to the presence of chlorides as well as of sulfur compounds (**Figure 4**). The presence of chlorine in coastal behaves as a catalyst, resulting in premature deterioration of the coatings, attacking the substrate material (**Figure 4(b)**).

In the case of arid climate deterioration occurs in minor proportion, however the presence of moisture combined with the high operating temperatures of the devices (25˚C - 300˚C) lead to the generation of aqueous phases giving rise to detachment of the coating's connectors (**Figure 5**).

In the case of connectors from regions of very warm weather prevailing-warm semidry spalling occurs to a lesser extent with respect to atmospheres

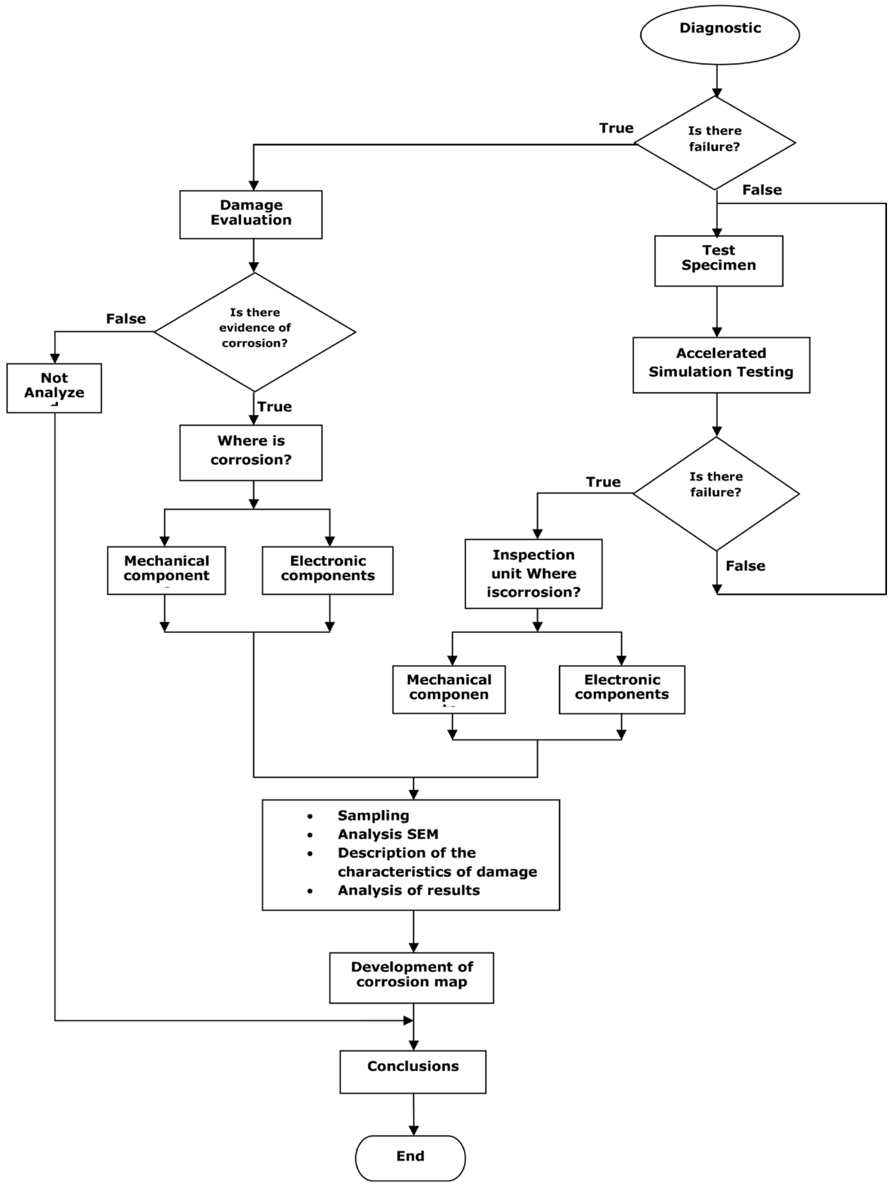
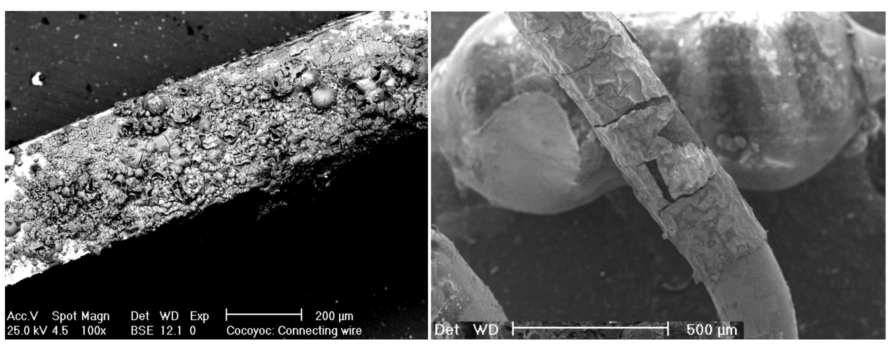
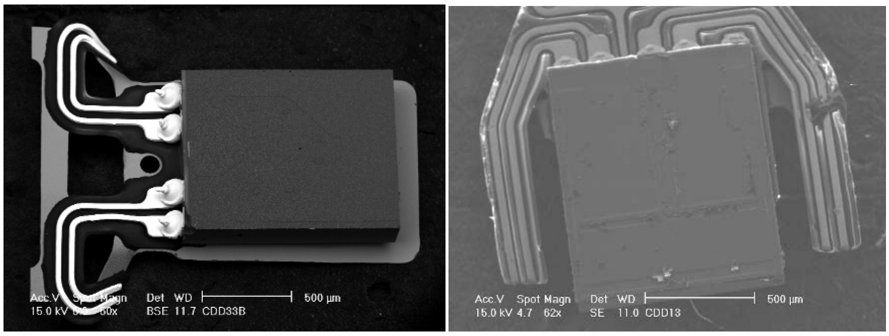


Figure 3. Methodology used for analysis and determination of damage to electrical devices.



(a) (b)

Figure 4. (a) Products of corrosion on a copper wire coated with nickel 100×; (b) Connector of resistance suffered by the detachment of the coating [3].



(a) (b)

Figure 5. (a) Head of read-write new hard disk with gold connectors; (b) Presence of condensate and detachment of the coating on connectors [12].

Table 2. Maximum permissible levels of major pollutants according to the values established for humans. Whereas these values accelerate testing have to be 100 times the permitted limit.

Pollutant	Permissible range
Ozone (O_3)	0.110 ppm (a maximum at one hour)
Sulfur dioxide (SO_2)	0.130 ppm (a maximum at 24 hours)
Nitrogen dioxide (NO_2)	0.210 ppm (a maximum at one hour)
Carbon monoxide (CO)	11 ppm (average daily maximum 8 hours)
Particles PM 10 µm	150 µg/m^3 (maximum at 24 hours)
Particles PM 2.5 µm	65 µg/m^3 (maximum at 24 hours)
Particles PST	260 µg/m^3 (maximum at 24 hours)

industrial, marine or combinations of both **Figure 6(a)**. The elements which are composed of aluminum alloys suffer wear on the surfaces leading to the possible presence of corrosive phenomena due to the detachment of the magnetic coating, with the presence of nickel oxide, **Figure 6(b)**.

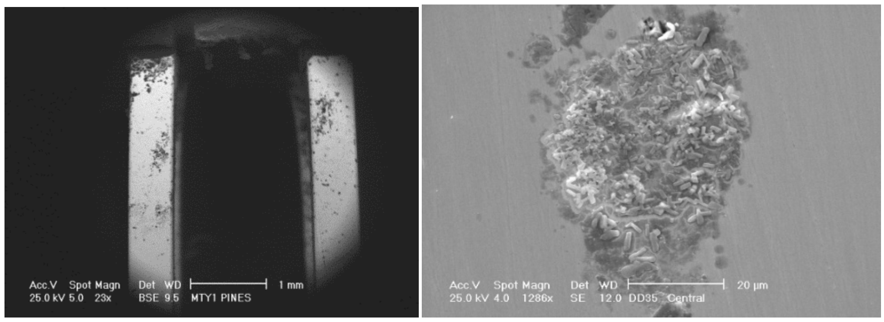
Quantification performed on specimens indicates that the pollutants are the most representative SO_2 (from 2% to 20% of the quantification) and nitrogen oxides (NO_x) in both cases for industrial and urban areas.

After the evaluation of the specimens under study were assigned a level of impairment, ranking in the order of 1 to 5, defining them as follows:

Low (1). Electronic devices (integrated circuits) present evidence of deterioration such as key changes in electrical terminals. Is required for inspection using scanning electron microscopy, which will determine the location of the area under study the device.

Medium-Low (2). The devices exhibited some accumulation of condensate dust affects the continuity and signal transfer. Typically occur primarily in printed circuit boards, power pins, connectors. Rural-urban atmosphere.

Medium (3). The main pollutants are NO_x, SO_2, CO_2, Ozone, being agents that accelerate corrosion processes [10] generated by motor vehicles coupled with the presence of existing industry in the region evaluated.



(a) (b)

Figure 6. (a) Detachment of the coating connectors nickel oxide presenting in the connecting region [6]; (b) Surface magnetic data storage, with filiform deposits, detachment product of the magnetic coating (1286×), presence of nickel [17].

Medium-High (4). Condensate accumulation is more likely in so-called "critical areas" (small spaces where connections are located), considering changes in %RH, high temperatures and presence of contaminants. Typically, this happens on the Pacific coast and Gulf coast of Mexico.

High (5). Notable deterioration having mass loss in terminals and other elements of electronic devices. At this stage of deterioration is possible to see at a glance evidence of corrosion. The regions with greater aggressiveness are the Isthmus of Tehuantepec, as well as regions that develop marine oil activity being atmospheres-industrial.

With the data collected has developed a map of atmospheric corrosion for electronic equipment considering all those parameters set out in Standard [8] (**Figure 7**).

6. Conclusions

The devices from the Gulf of Mexico region, present in greater proportion deterioration caused by high relative humidity, temperature, presence of chlorides and air pollutants, the samples obtained from this region show signs of accumulation of condensate, leading to difficulties in device operation.

In the center of the country, the factors that lead to corrosion are the pollutants from mobile sources and industrial activity, whereas particulate matter, being an important factor in the damage of those components and connection terminals. The low relative humidity that exists in this region results in lower rates of damage in electronic equipment.

It is confirmed that the miniaturization of electronic components leads to the presence of deterioration due to the accumulation of condensate deposits generating that promote corrosive phenomenon, as a result has to be the total sample tends to 44% product just to have evidence of this trend.

It is noteworthy that accelerated tests performed in laboratories UDIATEM, allows correlating the deterioration in electronic devices with the suffering in the field, allowing the prediction of material behavior. As data in both field and specimens in laboratory tests, SO_2, is the pollutant with the greatest presence in the

Climate	Corrosivity degree
Tropical - highly tropical / Arid - highly arid	
Semitropical /Subhumid	
Semitropical subhumid /Semiarid temperate - subhumid	
Tropical - semitropical / Humid - subhumid	
Highly tropical - tropical / Humid highly tropical - tropical / Arid - highly arid	

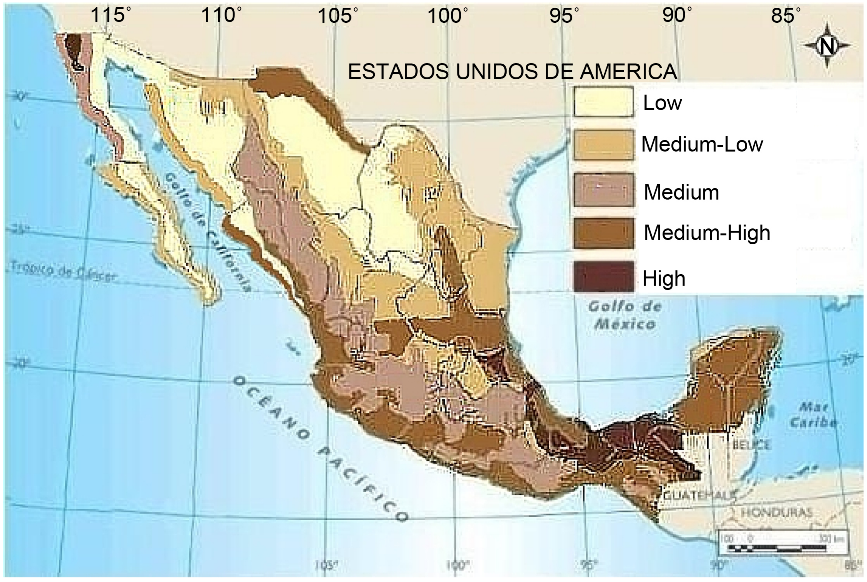


Figure 7. Classification of the degree of atmospheric corrosion of the regions evaluated.

deterioration of electronic components.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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