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Spectroscopy Analysis of Corrosion in the Electronic Industry Influenced by Santa Ana Winds in Marine Environments of Mexico

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1. Introduction

Climate change in some regions of the world is due to the effect of variations meteorological phenomenon, such as El Niño southern Oscillation (ENOS), which occasioning rainfalls in winter and even flooding, cold fronts and tropical cyclones in Baja California. Santa Ana winds (SAW) are influenced by ENOS, originated in the Santa Ana Canyon in the Mojave desert (Traviña et al, 2002), which cause rapidly changes in the climate conditions in the south west of California, USA y northwest of Baja California, Mexico. SAW are developed when the desert is cold, and are presented most commonly during autumn and spring seasons. This originates fast temperature rises and relative humidity (RH) drops, causing damage in the vegetation of these zones and changes in the meteorological conditions affecting the environments in indoor of industrial plants. Due to drastic changes in temperature and humidity in indoors of companies by SAW, an effect of strong transitions of these climatic factors occur which in combination with air pollutants as sulphurs and chlorides generate deterioration of copper metals of electronic machines and equipments. Analysis of raw materials used in electronic devices and electrical failures of electronic components were carried out in 15 companies in the coast of Baja California, Mexico. This study presents an analysis of winter of 2009, early spring of 2010 and late autumn of 2010. Humidity and temperature ranges of these winds can change rapidly from dry to wet, cold to warm and reverted in some hours. These several variations influence the corrosion rate of copper electrical connectors and connections of electronic equipments near the coast, installed in industrial parks of the northwest of Mexico in marine environments. In this region are located two important cities: Tijuana in the border with San Diego, California where was evaluated this phenomenon in ten companies and in Ensenada at 100 km. near the USA-Mexico border, with five industrial plants analyzed. The amount of defective devices increased in 25% and failures in electronic machines and equipments in 28% in the period of SAW occurred, compared with other seasons. In addition, 100% of raw materials located in warehouses of industrial companies, 33% were unusable. Auger electron spectroscopy (AES) technique was applied to determine the corrosion products in electrical connections and connectors of industrial electronic devices, equipments and machines.

1.1 Electronics industry

The electronics industry has grown over the past fifty years, contributing to the economy. Particularly in the Baja California State located in the northwest of Mexico, these companies have prospered in the industrial parks of Tijuana and Ensenada, on the Pacific Ocean considered as a marine region. In this environment, during winter and summer, the climate main factors at indoor conditions: humidity and temperature, affect electronic devices and industrial machines (Lopez et al, 2007). The change of climate in indoor of electronic plants is due to the variation of humidity, temperature, solar radiation, concentration of air pollutants such as CO, SO_2, H_2S, NO_X, O_3 and solid particles $Pm_{2.5}$ and Pm_{10}. The air pollutants and solid particles are monitored by Environmental Monitoring Stations (EMS) in Tijuana. While, SO_X and Cl^- were determined in Ensenada by Sulfatation Plates Technique (SPT) and Wet Candle Method (WCM), and metallic probes and in both cities were analyzed by AES. Electronic equipments installed inside the plants are fitted with copper components since they exhibit electrical and thermal conductivity. With the deterioration of copper, the equipment functionality decreases, generating failures and economic losses. This equipment is exposed to a wide range of indoor aggressive environments causing corrosion damage.

1.2 Atmospheric pollution

Gaseous and solid airborne pollutants comprises small dust particles hydrogen sulfide (H_2S), sulfur dioxide (SO_2), chloride ions (Cl^-) and nitrogen oxides (NO_X) which are capable of penetrating into indoor areas of the industrial plants through inlets of air filtering systems. These pollutants generate aggressive indoor environments in combination with humidity and temperature, producing corrosion damage of metallic components of electronic equipment. In spite of the existing corrosion prevention and protection system as well as application of electronic industry standards, corrosion control is not easy in specific climatic regions, especially in arid and marine regions (Dillon, 2000). Arid zones are typical, with RH ranging from 30% to 90% in summer with temperatures higher than 40°C and winter temperatures lower than 5°C. In marine environments, the RH is around 20% to 80% and temperatures in summer arises 35°C and diminishing to 3°C in winter. These factors, promoted by anthropogenic and natural activities facilitate the corrosion of the copper components (Valdez et al, 2006). The corrosion of copper specimens was evaluated by the gravimetric method; it was correlated with the minimum, average and maximum RH and outdoor temperature values in different seasonal periods, which affect the indoor climate plants. The efficiency of the electrical behavior of copper components in electronic devices is a function of the amount of humidity and pollutants present in the indoor environment (Veleva et al, 2008).

1.3 SAW and their effect on climate factors

A weather phenomenon in the region of California, USA and Baja California, Mexico, is SAW, which appears in finals of autumn and early of winter and spring (Traviña et al, 2002). This leads sometimes drastic changes in humidity and outdoor temperature affecting the indoor environments of industrial plants, originating in the manufacturing processes failures in electronic devices and equipments, causing low yielding. Moisture is the most important climatic factor that has a negative effect of this phenomenon, decreasing in certain periods of this meteorological phenomenon from values of 80% to 30%. SAW pass through the mountain and sometimes reach the hurricane force. The combination of wind, heat, and dryness generates dry vegetation and thus is an explosive fuel for fires acquaintances and often devastates the region. Though winds are often of a destructive nature, may have some positive results too. They can make the cold water rises from the ocean bottom to top, dragging many nutrients that ultimately benefit the fishery. As winds blow over the ocean, the temperatures of the sea surface fall around 4 ° C (7 °F), indicating an upwelling of deep ocean water. The evaporation process originated by SAW generates increases of temperatures by about in 5 º C. These variations modify the physicochemical properties of metallic materials and occur in some times a partial deterioration and in a few times after the beginning of SAW originates the corrosion in metallic materials as copper. This concerned to companies for the economic losses of defective electronic products and promotes rapidly the corrosion process on connectors and electrical connections and thus causing electrical failures, malfunctioning in electronic equipment and in some cases stops the manufacturing line. This causes warm climates, causing deterioration in some metallic materials used in the electronic connectors and connections such as copper. This decrease the quality of the articles manufactured in this region and generates economic losses (Lopez et al, 2007). When variations of humidity are very drastic, occurs several variations of temperature and therefore the electronic equipments and devices suffer changes in their functionality. To measure humidity ranges, is necessary install sensors in indoor of industrial plants be in contact with environments.. This study in this region is important by the influence of pressure difference of air mass between the mountains of California, United States and marine areas of northwestern of Mexico country, where companies are located in these the cities: Ensenada (300,000 people) and Tijuana (2,000, 000 people) (CONAPO, 2010). An analysis of wind direction and speed was made in the seasons studied to correlate this climate factors with the electrical failures of electronic equipments (Table 1).

Month	Wind Direction (º)		Wind Speed, m / s	
	Ensenada	Tijuana	Ensenada	Tijuana
January	66	72	14	11
February	69	70	16	13
March	67	69	14	12
April	61	63	18	14
May	223	228	10	7
June	228	234	11	9
July	192	198	14	10
August	195	201	13	11
September	206	211	10	8
October	204	207	11	8
November	63	69	8	6
December	67	74	9	6

Table 1. Analysis of wind in Ensenada and Tijuana (2010)

Wind direction from January to April and November to December was from southwest to northeast (60º to 70º), and in May to October, winds were reverted to the same direction (180º to 240º) and wind speed was at velocities less of 20 m/s. In the months that SAW is presented, RH decreased from 95% to 40% and temperature increased from 35 °C to 20 °C very fast in some hours in indoor of industrial plants.

1.4 Climate factors vs. electrical failures

Electronic equipment and machines of industrial plants consist of printed circuit boards, also called e-cards. The lifetime of these electronic components is according to the type of material, operation and exposition to environment. In some occasions, the durability decreases by the exposition to air pollutants and climatic factors, mainly drastic variations of humidity and temperature (Veleva et al, 2008, Lopez B.G. et al., 2010). Engineering design, manufacturing methods wrongs and inadequate mechanical movements generate improper installations. E-cards are constituted of a lot of electronic devices and are installed according to their operation, with sections separated with insulators to avoid electrical connections between undesirable zones (analog or digital signals), power (high and low), speed (high and low) and types of printed boards. There are a variety of electronic components, which are classified according to wave (sine, triangular, square or linear). In this study, an analysis of climate factors and electrical failures of electronic equipments installed in indoor of industrial plants of these marine zones was made (Figure 1).

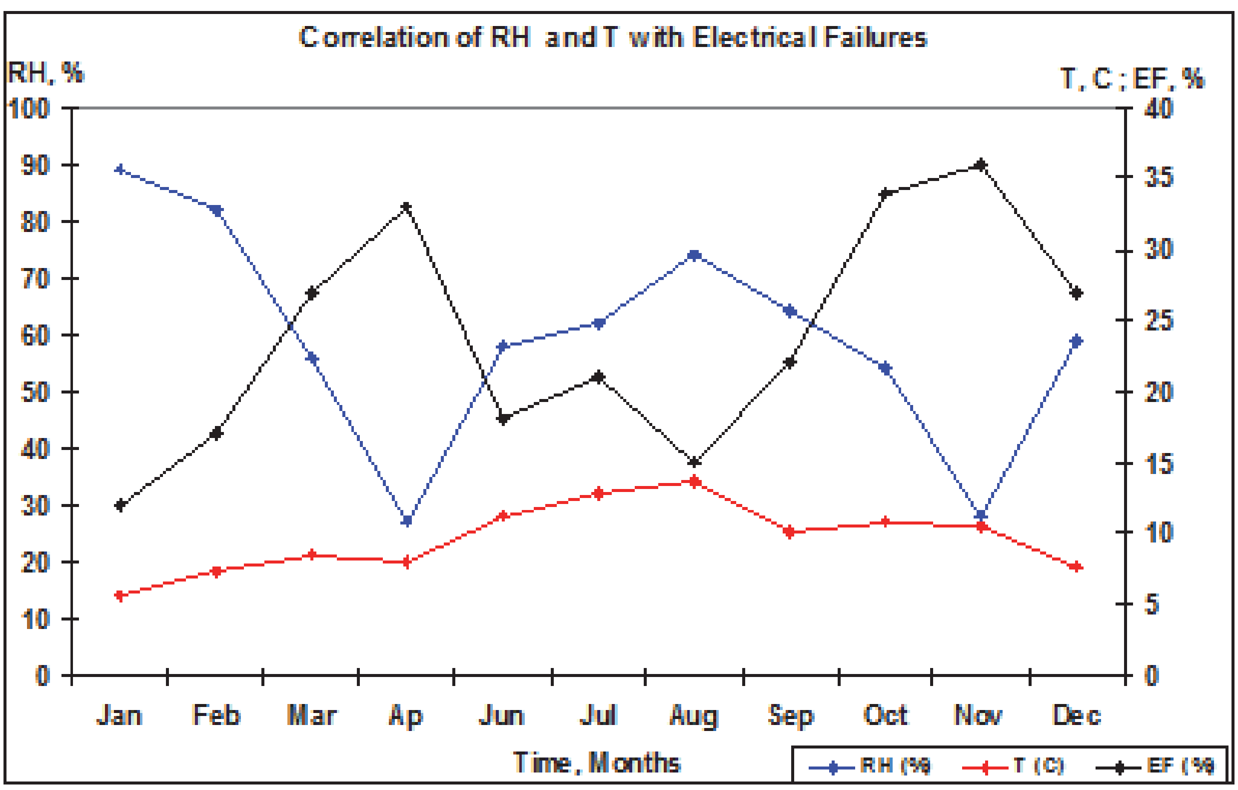


Fig. 1. Correlation of climate factors with electrical failures in industrial plants (2010).

In the absence of SAW, values of RH were in the range of 80% to 90% and temperatures variety from around 15 ºC to 30 ºC and electrical failures by an average of 20% at month.

When SAW were presented, RH diminishes to around of 30% and temperatures increases by 5 ºC and occurring electrical failures that are increased around 50%.

2. Materials and methods

Copper is used in electronic devices and equipments for the manufacturing of electrical connections and connectors, t for its good electrical and thermal conductivity. Nevertheless, is very susceptible to corrosion at the indoor polluted conditions.

2.1 Climate factors

Moisture content for interior environments modifies the physicochemical properties of metallic materials and increases strongly their micro and nano deterioration by the variation of air moist to dry, causing warm climates very quickly (Zlatev et al, 2009, Cole, 2004). Climate is composed of several parameters, where the relative humidity and temperature are the most important in the damage to these materials (ASHRAE, 1999), expressed with their measurements units and instruments (Table 2). Scientists that analyze deterioration of materials and climatic conditions in indoor of industrial plants, consider that a bad operation of industrial equipments is due to the presence of drastic changes in humidity and temperature in certain times of the year (Lopez, 2008), as is expressed in ISO 9223 (ISO9223, 1992). Experts in industrial productivity and quality manufacturing consider that in these region defective products and electrical failures in electronic equipment of industrial plants are presented and create a tense in managers in the companies because causes great economic losses.

Factors	Measuring Instrument	Unit
Humidity	Hygrometer	%
Temperature	Thermometer	◦ C
Atmospheric pressure	Barometer	mmHg
Solar radiation	Pyranometer	W / m2
Pluvial Precipitation	Rain gauge	mm
Wind direction	Wind vane	◦ Grade
Wind speed	Anemometer	m/s

Table 2. Climatic factors and their measurement

2.2 Corrosion testing

Copper specimens for corrosion testing were exposed in at indoor conditions of electronics plants for a period of two years in Mexicali and in Ensenada. The specimens corrosion was evaluated according to the ASTM standards G 1, G 4, G 31 (ASTM, 2000), and correlated with the minimum, average and maximum outdoor RH, TOW and temperature parameters (ISO 11844-1, 2006). The electronic plants in Tijuana where they are located in industrial parks while in Ensenada, plants are located at distances ranged between 1 km to 10 from the sea shore. Rectangular specimens with dimensions of 2.5 cm. x 1 cm. x 0.5 cm. were cleaned by immersion in an isopropyl alcohol ultrasound bath for 15 minutes. Immediately after cleaning the copper specimens were placed in sealed plastic bags, ready to be installed in the test indoor sites. After each exposure period the specimens were removed, cleaned and weighed to obtain the weight loss and to calculate the corrosion rates (CR) (ISO 11844, 2005). The corrosion products morphology was examined with an optical microscope. The most active gases are hydrogen sulfide (H_2S) and SO_X. H_2S is a corrosive and toxic pollutant which originates from municipal sewage (Moncmanova, 2007; Lopez B. et al, 2010).

2.3 Numerical analysis

A mathematical correlation was made in MatLab software (Duncan et al, 2005) to determine the corrosivity levels (CL) in indoors of electronics industry in Mexicali an Ensenada, With this analysis find out the deterioration grade (DG) of metallic probes of copper, correlating the climate factors (humidity and temperature), airs pollutants (CO, NO_2, O_3 and SO_2), from outdoor sources that penetrate by inlets or air-conditioning systems, to indoors of industrial plants and corrosion rate (CR).

2.4 Characterization of atmospheric corrosion in industrial plants

Corrosion in indoor atmospheres is influenced by external climatic conditions generating the time of wetness (TOW). TOW is an important factor in the generation of corrosion in electrical connectors and connections of electronic devices, was obtained with variations of RH and temperature, showing high rates in some periods of winter and summer by the SAW phenomena. This is an important factor to determine the type of corrosion that occurs in metals and the levels which increases the corrosion rate (CR). In this process, cells formed by corrosion process, originate galvanic corrosion, for example in the binding of platinum and zinc with 0.2 volts, which are capable of cause an electrical failure in electronic devices and equipments. The origin of corrosion in indoors of industrial plants is due to climatic factors and the concentration of air pollutants. In winter, corrosion is generated uniformly by wetting film formed on metals, and in summer in the materials analyzed appears small tarnishings, as a result of some air pollutants and drops adhered to metals surface. The TOW obtained of variations of RH and temperatures with values over of 80% and 0 ° C, that is characteristic of three cities evaluated, is an important factor in the origination if corrosion in metals. All regions analyzed, showed corrosivity levels (minimum and maximum), that are a cause of generation of aggressive environments, and the corrosion process. The period of copper exposure, appears small tarnishing in some areas of metallic probes, which caused pitting and uniform corrosion (Lopez , 2008).

2.5 Spectroscopy examination techniques

The examination technique with the Auger Electron Spectroscopy (AES) was used to determine the air pollutants that reacted with the copper surface of metallic probes and the morphology with the Auger map (Yves Van, 2008). Electrons flows through the instrument to generate low energy showed the topography of metals tested. Once it determines the chemical composition of elements and compounds in the specimens, and observed the air pollutants deposited on metals and know that they affect in the generation of the corrosion process. With this technique we knew in detail, quickly and with precision, the structural form and location of corrosion, which will determine the type of corrosion and know the techniques protection for the metals analyzed (Asami et al, 1997, Briggs, 1990)). The specimens were exposed in indoor of industrial plants with values of relative humidity and temperature over 90% and 20 ºC in winter and 80% and 15 ºC in summer, and removed for one, three and six months and analyzed with EDX and AES spectroscopy to identify the corrosion products formed on the copper surface. Metallic probes were exposed in periods of 1, 3 and 6 months showed tarnish in some regions, but from the seventh month to the final period of study, in the specimens appear corrosion on the full surface of copper, and corrosion rate decreases by the formation of a copper oxide film, serving as a protective layer. The analysis obtained by EDX and Auger S2 models was made with Ranger and ESCA / SAM 560 of Perkin Elmer. The Auger spectra showed the chemical composition and use the sputtering method to clean the copper surface, bombarding with Ar+ ion beam with energy of 5keV and current density of 0.3 uA / cm^3, to remove the CO2 pollution of the environment.

3. Results

The rapid transitions of temperature and humidity in indoor of companies caused by SAW and generate aggressive environments in combination with air pollutants generated in indoor of industrial plants and stays longer periods of time suspended in the air and causing more damaging in electronic equipments.

3.1 Deterioration of metals used in industrial plants

Ranges of RH and temperature were higher than 70% and 35ºC during the year in Tijuana and with a minimum of 20% and 30ºC in the periods of heat winds (early winter and spring) and maximum of 80% and 10ºC in the rest of the year in Ensenada area. Levels of humidity and temperature bigger 70% and 30 °C accelerated the rate of corrosion. In summer the corrosion rate was higher after one year in Tijuana and also was in Ensenada. For temperatures in the range from 25 ºC to 35 ºC, and RH level of 30% to 70%, the corrosion rate was very high. Furthermore, in winter, at temperatures around 15 ºC to 25 ºC and RH levels from 35% to 75%, water condensates on the metal surface and the copper corrosion rates increases very fast. Variations of RH in the range from 30% to 80% and temperatures from 0 ºC to 35 ºC, and concentrations of air pollutants such as sulfides and chlorides in this marine environments, exceeding the permitted levels for air quality standards, are also an important condition that favors corrosion. Corrosion processes can be accelerated in polluted atmospheres in the presence of variations of humidity and temperature. The origin of corrosion in metallic materials such as copper, used inside the electronics industry is due to the action of climatic factors and effect of air pollutants. In the autumn and winter, corrosion is generated by a film formed uniformly on metals, and in spring in these materials are pitting as a result of some small drops that adhere to certain areas of the metal surface (Lopez et al, 2010). This is partly of the variations of humidity and temperatures that is typical of this city during certain seasons of the year. Is necessary monitoring and control principally the relative humidity and hold the adequate range to permit the good functionality of the equipments and products to avoid defective products and electrical and mechanical failures of electronic equipments during the presence of SAW. The values of relative humidity and temperature were lower 40% and 20 ºC during the year. At beginning of spring season, the corrosion rate increases in the range 15 ºC to 30 ºC, with relative humidity level of 25% to 40%. Furthermore, in autumn and winter the several changes of RH and temperature, water condensates on the metal surface and the copper corrosion rates increases. At temperatures of 17 ºC to 25 ºC, with the variations drastically of RH levels, corrosion rate was high too (Table 2). The emissions of vehicles are an important factor source of air pollutants, are cars that is important in the marine zone and emissions of thermo electrical operations where the electricity is generated to this. The air pollutants affect on the metals and the corrosion rate depend on the pollutant concentration in air and their corrosion resistance in the region. The Cu_2O layer can be gradually dissolved in the acidic electrolyte formed in the presence of SO_2 and Cl^-. A computer based model of atmospheric corrosion has been used to simulate copper exposed to room temperature to 200 ppb SO_2, in combination with either NO_2 or O_3 at different concentrations.

Climate factors	Sulphur oxide (SO_2)				Nitrogen oxides (NO_X)				Ozone (O_3)			
	RH[a]	T[b]	C[c]	CR[d]	RH[a]	T[b]	C[c]	CR[d]	RH[a]	T[b]	C[c]	CR[d]
Spring												
Max	74.5	22.3	0.21	225	79.3	29.5	0.42	208	69.7	24.3	0.29	193
Min	22.7	10.2	0.18	17	29.6	11.7	0.28	109	21.5	12.5	0.12	145
Autumn												
Max	86.4	28.6	0.27	289	73.9	31.7	0.44	265	74.9	29.5	0.52	268
Min	26.4	19.4	0.16	174	25.4	12.7	0.19	168	18.7	14.8	0.18	203
Winter												
Max	69.2	22.6	0.48	324	85.1	25.7	0.56	231	79.9	28.9	0.67	273
Min	19.3	13.3	0.32	152	28.6	14.8	0.29	188	26.4	12.8	0.23	165

[a] RH. Relative Humidity (%) [b] T. Temperature (ºC)
[c] C. Concentration Level of Air Pollutant (ppm)
[d] CR- Corrosion rate (mg/m^2.year).; Source. Environmental Monitoring Stations.

Table 3. Effect of RH, temperature and air pollutants on the corrosion rate of copper in Tijuana.

3.2 Corrosivity levels analysis

Corrosivity levels (CL) represents the degradation grade (DG) of materials in according to the correlation of relative humidity, temperature and air pollutants concentration mentioned above. CR was calculated from the atmospheric pollution in indoor of electronics industry, indicating which air pollutants with major grade of damage to copper was dioxide sulphide (SO_2) and the ion chlorides (Cl^-) in both cities.

In both cities, RH was correlated with the major CR was 30% to 50% with temperatures of 25˚C to 40˚C. In summer CR was different than in winter, and in both environments (Figures 2 and 3). The electronics equipment corrodes at high humidity levels. Air pollutants such as CO, NO_X and sulfides penetrate through defects of the air conditioning systems. Corrosion phenomena affect connections of electronic equipment and other electronics components protected with plastic or metallic materials (Sankara et al, 2007). Atmospheric corrosion is an electrochemical phenomenon that occurs in the wet film formed on metal surfaces by climatic factors in Tijuana was presented pitting corrosion and in Ensenada was presented

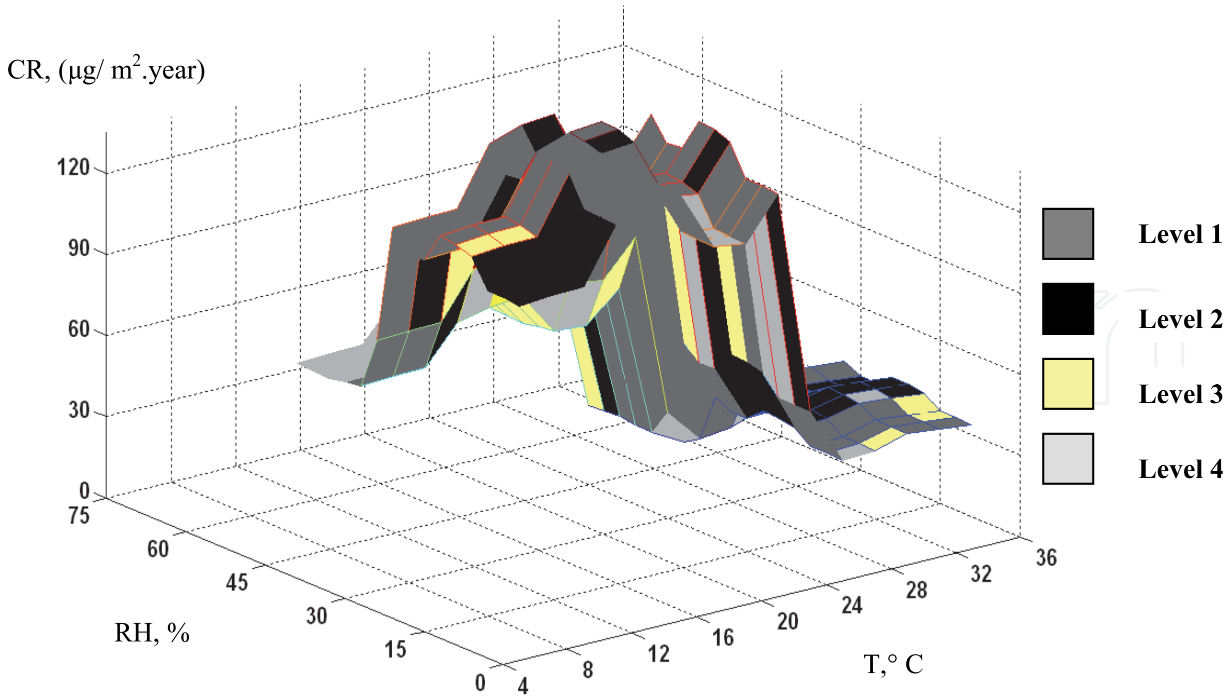


Fig. 2. CL of copper after one year of exposition in Ensenada (2010).

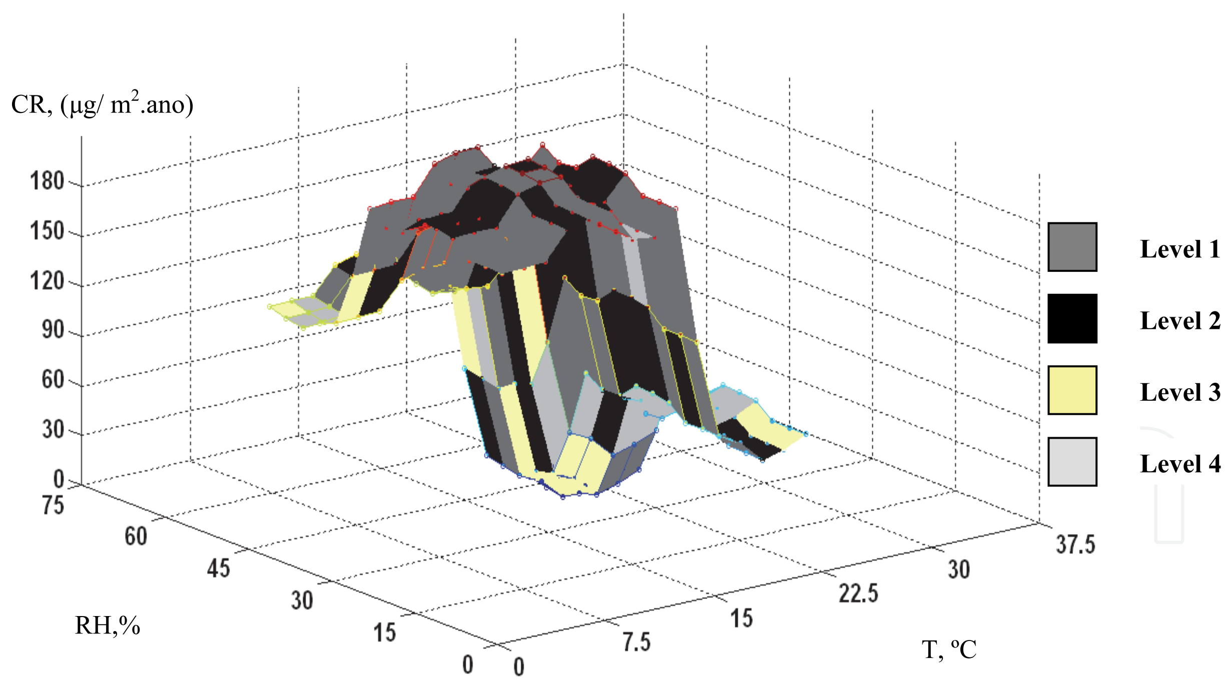


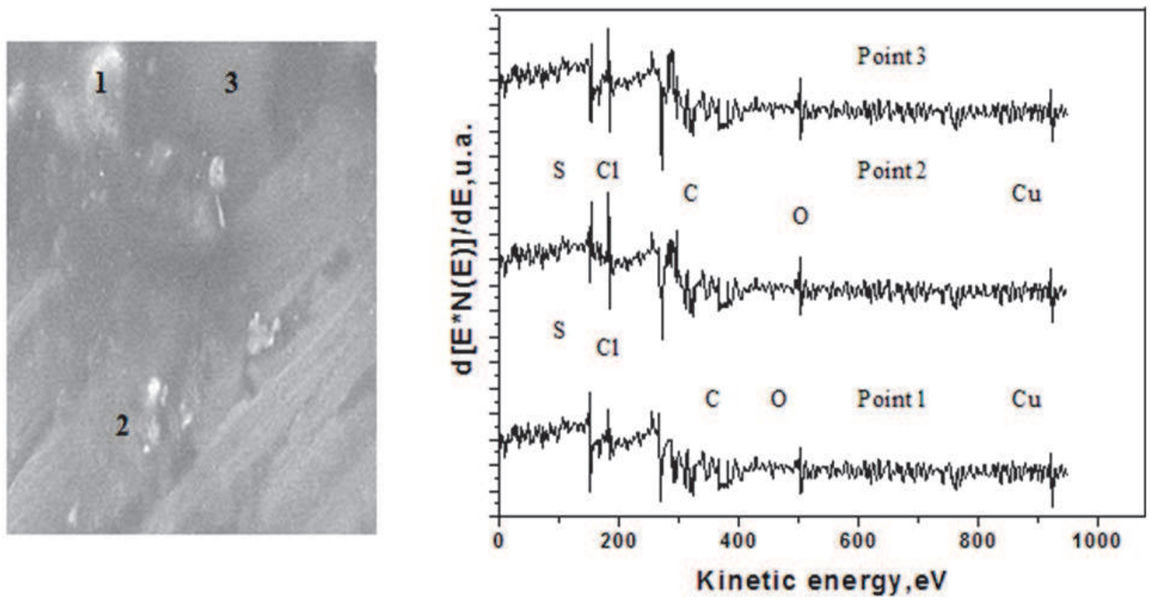
Fig. 3. CL of copper alter one year of exposition in Tijuana (2010).

the uniform corrosion. This behavior of corrosion was showed in the first month of the period of evaluation. Figure 2 shows the CL of indoors of electronics industry in Ensenada, indicating the level1, the major aggressive environment and levels 4 the high aggressiveness grade (AG) which generate high DG of this type of materials. Some sections of the graph, represents the different grades of AG, with high areas of level 1 and 2 and levels 3 and 4 exists in less percentage. This can generate failures in the electronic devices and equipments in indoor of industrial plants. RH and temperature ranges were from 30% to 75% and 20 ° C to 35° C with CR from 30 µg/m^2.year to 100 µg/m^2.year. The same was occurred in Tijuana city that is showed in figure 3. Evaluation of CL in Tijuana indicate that same range of levels presented in Ensenada, with RH and temperatures from 40% a 75% and 20 ° C to 35 ° C, with CR from 10 to 160 µg/m^2.year. Microcircuits, connectors and electrical contacts used in the electronics industry, are susceptible to atmospheric corrosion, which occurs in indoor plants in the industrial plants in Tijuana and Ensenada. Corrosion rates obtained in semi-arid testing points (Tijuana) is higher than those from the marine environments (Ensenada), since in the arid zone the principal air pollutant is H_2S and in the marine zones, predominate the Cl^- ion as the major corrosive. A comparative analysis, after six months of exposure of copper specimens shows higher levels of deterioration by corrosion in Tijuana regarding to the Ensenada results.

3.3 AES examination

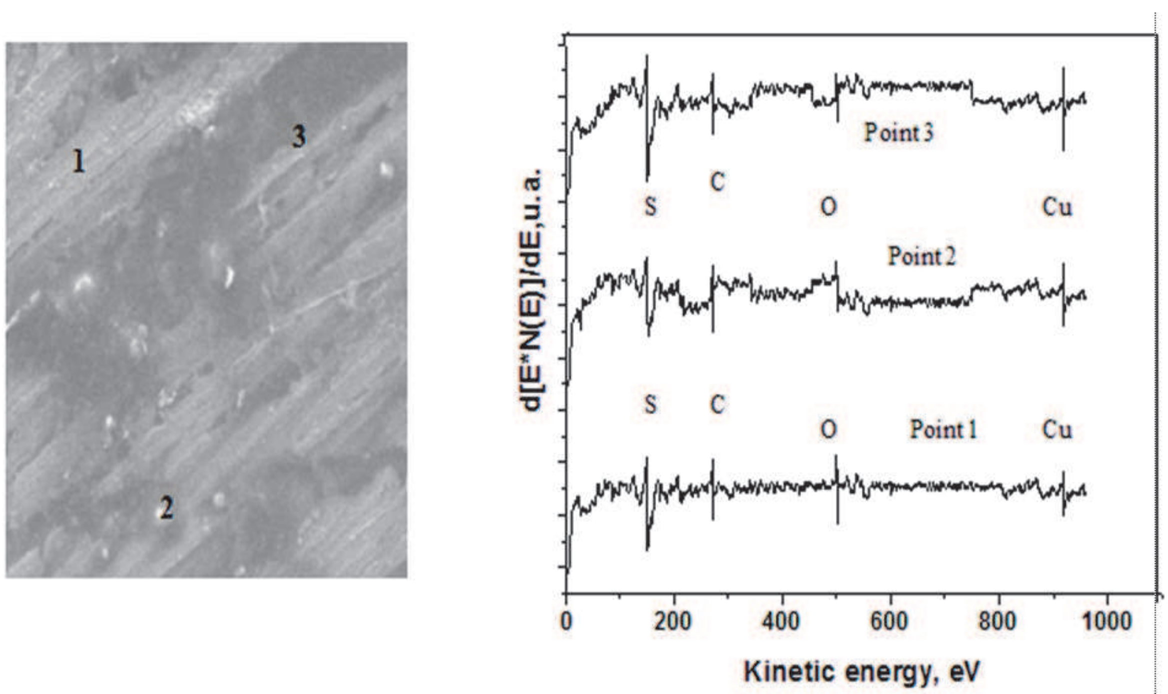
AES analyses were carried out to determine the corrosion products formed in the copper surface. Figure 1a show scanning electron micrograph (SEM) images of areas selected for AES analysis covered by the principal corrosion products which are rich in chlorides and sulphides in metallic specimens evaluated in both cities. The Auger map process was performed to analyze punctual zones, indicating the presence of Cl- and S as the main corrosive ions present in the copper corrosion products. The Auger spectra of Cu specimens was generated using a 5keV electron beam (Clark et al ,2006), which shows an analysis the chemical composition of the thin films formed in the Cu surface in Ensenada (Fig 2) and in Tijuana (Fig 3). The AES spectra of copper specimens installed in industrial plants in both cities show the surface analysis of three points evaluated in different zones of the metallic probes. The peaks of Cu appear between 905 and 915 eV, finding the chlorides and sulphides. In figure 2, the spectra reveals the presence of carbon and oxygen, chlorides and sulphides, with variable concentration in the chemical composition in the three regions analyzed, where the principal pollutant was Cl- ion. Figure 3 corresponds to the specimens installed in companies in Tijuana city. In the regions of copper surface analyzed were observed different concentrations of sulfur, carbon and oxygen, while the main air pollutant detected was H_2S. The atomic concentration (%) of the chemical elements in each spectrum was organized in Table 4. To draw this figures a program: sigma plot was applied. The spatial resolution of this technique is around 100 nm and a 1 nm depth resolution (Swart, 2010).

The metallic samples of 1, 3 and 6 months to the metals analyzed show localized corrosion with small spots and from the seventh month to the one year the spots were observed larger, being more concentrated corroded areas and generated uniform corrosion. Auger spectra show an analysis of the chemical composition and a microphotograph on the metals surface (Figure 4) and with the sputtering [14, 15] was observed the corrosion and passivity process that generate the copper oxide film to reduce corrosion. Air pollutants added to copper surface form thin layers in according to the adhesion grade, in some with more chloride ions (light color) and other with less concentration of sulphur (dark color) for the marine environment in Ensenada (Figure 4a) and elements with carbon oxide of the environment by the sensibility of the Auger equipments was showed in the spectra (Figure 4b). In the analysis of Auger spectra in Tijuana that is an arid environment, the major air pollutant that reacts with copper surface was the sulphur, represented by the Auger map (Figure 5a) with more dark sections without chloride ions, compared with the evaluation in Ensenada. Auger spectra indicate the air pollutants combined with CO_2 of the environment (Figure 5b). Table 4 represents the atomic concentration of metallic probes with the percentages of air pollutants and carbon and oxygen (Sankara et al, 2007, Clark, 2006).



(a) (b)

Fig. 4. Analysis of corrosion products of copper at one year of exposition: (a) Auger map and (b) AES in Ensenada (2010).



(a) (b)

Fig. 5. Analysis of corrosion products of copper at one year of exposition: (a) Auger map and (b) AES in Tijuana (2010).

Figures 6 and 7 show the Auger spectra at 1, 3 and 6 months of metallic coupons, after the cleaning process with Ar^+ ions, at 5 minutes. SEM and AES analyses were carried out to determine the corrosion products formed in the copper surface. Figures 6 and 7show the scanning electron micrograph (SEM) images of areas selected for AES analysis covered by the principal corrosion products which are rich in the both air pollutants mentioned above in both cities as the test results indicate. The Auger map process was performed to analyze punctual zones, indicating the presence of Cl^- and $S^=$ as the main corrosive ions present in the copper corrosion products. The Auger spectra of Cu specimens was generated using a 5keV electron beam, which shows an analysis the chemical composition of the thin films formed in the Cu surface in Ensenada (Fig 2) and in Tijuana (Fig 3). The AES spectra of copper specimens installed in industrial plants in both cities show the surface analysis of three points evaluated in different zones of the metallic probes. The peaks of Cu appear between 905 and 915 eV, finding the chlorides and sulphides. In figure 6, the spectra reveals the presence of carbon and oxygen, chlorides and sulphides, with variable concentration in the chemical composition in the three regions analyzed, where the principal pollutant was Cl^- ion.

	Ensenada			TIJUANA		
Elements	Point 1	Point 2	Point 3	Point 1	Point 2	Point 3
C	36	29	29	24	26	23
Cl	12	32	31	X	X	X
Cu	13	11	12	19	21	26
O	8	12	13	26	23	19
S	31	16	15	31	30	32

Table 4. Atomic concentration (%) of metallic probes.

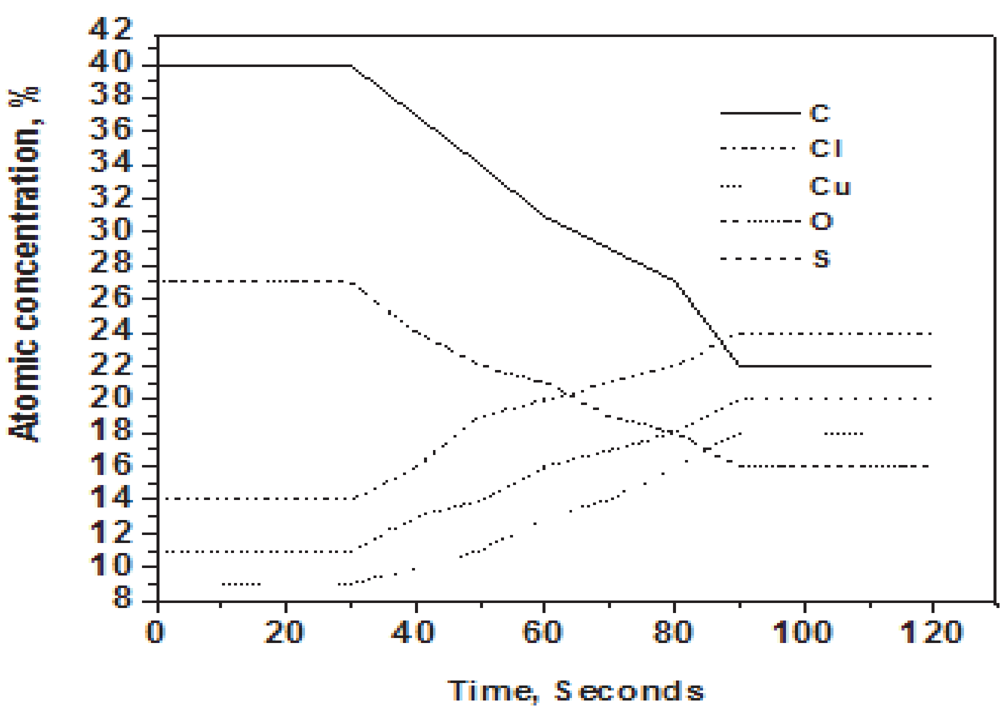


Fig. 6. Depth profile analysis in copper surface, Ensenada (2010).

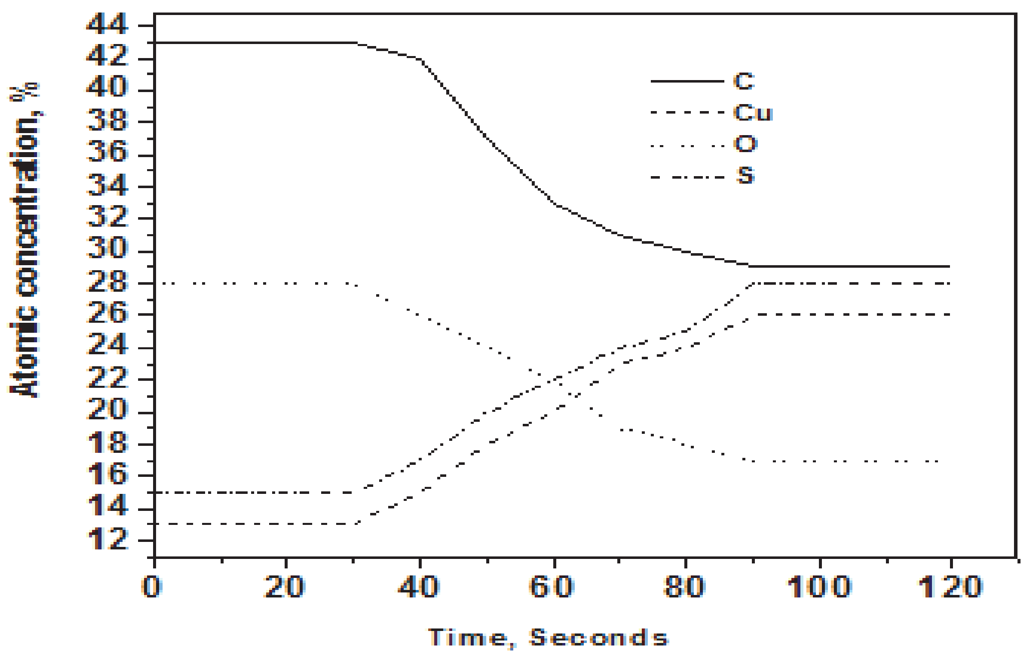


Fig. 7. Depth profile analysis in copper surface, Mexicali (2010).

The spectra reveal the importance of technical analysis with the Auger, which is evaluated with the formation of the films formed on copper surface thereby know the mechanism of corrosion in this metal. Auger depth profiles were collected on specimens of both cities, showed in figures 6 and 7. The depth profiling technique is defined by alternating cycles of Ar^{+}-ion sputtering to remove a thin layer (5 to 10 Å) of air pollutants that react with the copper surface and their characterization in some regions with the AES technique. In figures 6 and 7, chloride and sulfur located between carbide particles sputtered completely off during the first sputtering cycle (10 Å). A small chloride and sulphide persisted deeper into the carbide particles (point 2). In figure 6, the depth profile indicates a small presence of sulfur between the carbide particles.

4. Discussion

The air pollutants affect the deterioration of copper and its corrosion behavior and resistance. The principal anthropogenic and natural sources in indoor of industrial plants in both cities of corrosive pollutants are the gas emissions of vehicles, chloride particles from the marine environment and sulfides from the thermoelectrical power plants in Tijuana, Rosarito and Ensenada. Generation of corrosion in industrial plants has been an important factor in the last 30 years by the complexity of the electro-electronic devices and equipments that are qualified by the market demand, their operation and reliability (Lopez et al, 2007). The competition is governed by manufacture of electronic devices and equipments, increasing the necessity of develop various and great quantity of operations and decrease their size at a low cost (Valdez at al, 2006). This been has the principal effect to change the designs with smaller spaces between electronic devices and the use of new materials in electrical connectors and connections of electronic devices and equipments. Other factors are the uncontrolled climates of indoors, that promote the generation of corrosion (Lopez, 2008).

In most cases companies do not know the phenomenon of corrosion or not are considered as an important factor, until it causes a failure in some electronic devices and equipments, and stop the manufacture process.

5. Conclusion

Miniaturization and the requirement for high component density of small electronic devices need closer spacing and thinner metallic paths affected by corrosion and electrical failures. Copper exposed to air pollutants reveal that an increase on their concentrations at outdoor conditions has a critical impact on the indoor corrosion process in arid and marine environments. RH values higher than 75 % and concentration of air pollutants, promotes corrosion. The composition of the copper surface was obtained by the Auger spectra, showing localized corrosion from the first month to six months of exposure in both cities, and uniform corrosion. Particulate and gaseous pollutants, deposited on metal surfaces of micro-electronic components, are generated at residential and industrial zones with high motor traffic and operations in warehouses and offices, which promote corrosion. Electronic equipment installed in industrial plants are exposed to environmental factors in indoor and outdoor conditions. The corrosion of copper in indoor environments may be viewed as a variation of outdoor atmospheric corrosion. In contrast to outdoor exposure, in an indoor environment the wet film on the metal surface is thinner and it is often governed by relatively constant controlled humidity conditions. Sometimes the indoor environment temperature and RH are controlled and as a consequence, the amount of adsorbed water on surfaces is minimal and is constrained within reasonably tight limits. Currently measuring equipment such surface analysis techniques as AES was used in most of the industrial processes are very used to detect particles added to the metallic surfaces. In this study, Auger spectroscopy was made to detect the principal components added to surface of electrical connections and connectors. With this techniques, can obtain results of the chemical reaction the atmospheric agents that forms the thin films in metals of copper. Miniaturization and the requirement for high component density of small electronic devices need closer spacing and thinner metallic paths that originates the corrosion phenomena and electrical failures in the connections. Uniform and localized corrosion mechanisms are detected in electronic systems. Particulate and gaseous pollutants deposited on metal surfaces of micro-electronic components generated by traffic vehicles and operations of thermo electrical located at 50 kms of each city and provide electricity to this region in warehouses and offices, and promote corrosion. Electronic equipments installed in industrial plants are exposed to environmental factors, indoor and outdoor.

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7. References

Annual Book of ASTM Standards, 2000, Wear and Erosion: Metal Corrosion, Vol. 03.02.

ASHRAE; Handbook; Heating, Ventilating and Ari-Conditioning; applications; *American Society of Heating*, Refrigerating and Air-Conditioning Engineers Inc.; 1999.

Asami K., Kikuchi M. and Hashimoto K.; An auger electron spectroscopic study of the corrosion behavior of an amorphous $Zr_{40}Cu_{60}$ alloy; *Corrosion Science*; Volume 39, Issue 1, January 1997, Pages 95-106; 1997.

Briggs D. and Seah M. P., Practical surface analysis, Second Edition, Volume 1 Auger and XPS, Photoelectron Spectroscopy,1990.

Clark A. E., Pantan C. G, Hench L. L; Auger Spectroscopic Analysis of Bioglass Corrosion Films; *Journal of the American Ceramic Society*; Volume 59 Issue 1-2, Pages 37–39; 2006.

Cole S. and Paterson D. A.; Relation of atmospheric pollution and the generation of corrosion in metals of copper, steel and nickel; Corrosion Engineering; 2004.

Consejo Nacional de Poblacion (CNP), Anuario Estadistico, Censo de Poblacion, Gobierno de Mexico, 2010.

Dillon P., MTI & DOE Launch Project Partnerships, Communications Materials Technology Institute of the Chemical Process Industries, Inc, 2000.

Duncan Balachandran, Walsh Harold; An Engineer's Guide to MATLAB, 2e: with Applications Electrical Systems, ; Prentice Hall, 2005. ISO 9223:1992, Corrosion of metals and alloys, Corrosivity of Atmospheres, Classification. ISO 11844-2:2005. Corrosion of metals and alloys - Classification of low corrosivity of indoor atmospheres - Determination and estimation attack in indoor atmospheres. ISO, Geneva, 2005. ISO 11844-1:2006. Corrosion of metals and alloys - Classification of low corrosivity of indoor atmospheres- Determination and estimation of indoor corrosivity. ISO, Geneva, 2006.

Lopez B.G.; Ph.D. Thesis; Caracterización de la corrosión en materiales metálicos de la industria electrónica en Mexicali, B.C., 2008 (Spanish).

Lopez B.G., Valdez S.B., Zlatev K.R., Flores P.J., Carrillo B.M. and Schorr W. M.; Corrosion *of metals at* indoor conditions in the electronics manufacturing industry; *Anti-Corrosion Methods and Materials*; 2007.

Lopez B. G., Valdez S. B., Schorr W. M., Tiznado V. H., Soto H. G., Influence of climate factors on copper corrosion in electronic equipments and devices, *Anti-Corrosion Methods and Materials*; 2010.

Lopez G., Tiznado H., Soto G., De la Cruz W., Valdez B., Schorr M., Zlatev R.; "Corrosion de dispositivos electronicos por contaminacion atmosferica en intertiores de plantas de ambientes aridos y marinos; *Nova Scientia*, ISSN 2007-0705; 2010 (in Spanish).

Lopez B. Gustavo, Valdez S. Benjamin, Schorr W. Miguel, Zlatev R., Tiznado V. Hugo, Soto H. Gerardo, De la Cruz W.; AES in corrosion of electronic devices in arid in marine environments; *AntiCorrosion Methods and Materials*; (in press).

Moncmanova A. Ed. ; Environmental Deterioration of Materials, WITPress, 2007, pp 108-112.

Sankara Narayanan, Young Woo Park and Kang Yong Lee, Science direct, Elsevier B.V, "Fretting-corrosion mapping of tin-plated copper alloy contacts", Volume 262, Issues 1-2, 4 January 2007, Pag 228-233.

Swart H.C., Terblans J.J., Coetsee E., Kumar V., Ntwaeaborwa O.M.,Dhlamini M.S., Dolo J.J., Auger electron spectroscopy and X-ray photoelectron spectroscopy study of the electron-stimulated surface chemical reaction mechanism for phosphor degradation, Surface and Interface Analysis, Accesed: http://www3.interscience.wiley.com/journal/123317463/abstract, 2010.

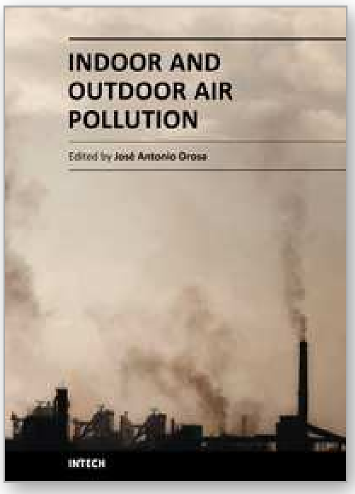
Traviña A., Ortiz-Figueroa M., Cosio M.; Santa Ana winds and upwelling filaments off the Northern Baja California winds; Journal of Dynamic of Atmospheres and Oceans; 2002 .

Valdez B. and Schorr M.; El control de la corrosión en la industria electrónica; *Revista Ciencia*; 2006 (Spanish).

Veleva L., Valdez B., Lopez G., Vargas L. and Flores J.; Atmospheric corrosion of electro-electronics metals in urban desert simulated indoor environment; *Corrosion Engineering Science and Technology*; 2008.

Yves Van Ingelgem *, Isabelle Vandendael, Jean Vereecken, Annick Hubin, Study of copper corrosion products formed during localized corrosion using field emission Auger electron spectroscopy, *Surface and Interface Analysis*, Volume 40 Issue 3-4, Pages 273 –276, 2008.

Zlatev R., Valdez B., Stoycheva M., Vargas L., Lopez G., Schorr M.; Simpsoium 16: NACE "Corrosion and Metallurgy"; IMRC 2009, Cancun, Mexico.



Indoor and Outdoor Air Pollution

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Air pollutants are continuously released from numerous sources into the atmosphere. Several studies have been carried out on the quantification of pollutants and their consequences on public health. Identification of the source characteristics of air pollution is an important step in the development of regional air quality control strategies. Air quality is a measure of the degree of ambient atmospheric pollution. Deterioration and damage to both public health and environment due to poor air quality have been recognized at a legislative and international level. In consequence, indoor and outdoor air quality must also be considered. This book tries to reveal different points of view of the wide concept of air quality in two different sections. In this context, there will be an initial introductory chapter on the main concepts of air quality, following which there will be real case studies on outdoor and indoor air quality with an aim to provide a guideline for future standards and research works.