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# COMPARATIVE EVALUATION OF THE ENVIRONMENTAL ERGONOMICS FACTORS IN INDOORS OF THE ELECTRONICS INDUSTRY IN ARID AND MARINE ENVIRONMENTS OF THE NORTHWEST OF MEXICO

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## ABSTRACT

An investigation was made to evaluate the environmental ergonomics factors that had an effect on the operative yielding of workers of manufacturing areas of the electronics industry in two cities in the Baja California State of the Mexican Republic, such as the cities of Mexicali and Tijuana, located in the northwest of Mexico. These two cities represented in this scientific study two type of regions: arid in Mexicali and marine in Tijuana, and with this was made a comparative analysis, including the principal factors of the environmental ergonomics such as climate parameters (relative humidity and temperature), noise and vibrations of industrial machinery, level of luminosity in indoors of the ten industrial plants of the industrial electronics, which were evaluated .Also was analyzed presence of bad odors and inorganic air pollutants (derived from sulfur, nitrogen and carbon) and organic pollutants as microorganisms, provided from the enormous vehicular traffic and large number of industries in both cities. The presence of air pollutants mentioned above, caused the generation of Acute Respiratory Infection (ARI) in workers of the manufacturing areas and with this the productivity and quality levels decreased, due to the absence of experienced workers, and need use inexpert people that was making errors and with this, defective products manufactured. This investigation was made from 2018 to 2020, where in 2020 was made with a strict regulation by the presence of the Covid 19 pandemic.

**Keywords**. Environmental Ergonomics, Electronic Industry, Productivity, Quality, Arid and Marine Zones.

## 1. INTRODUCTION

The environmental ergonomics is a fundamental section of the ergonomics topic, which actually have a relevant aspect in the manufacturing areas of the industries in the world, because health and work activities government institutions in every country was detected an increase of workers of industrial processes of industrial plants with any symptom of health respect of pain or discomfort in arms, back, fingers, hands, head, legs, shoulders and waist, principally (Devlin, 2018). This generates a lot cost to the health government institutions of any country and to the industrial plants located in any place of the world. Also, the environmental ergonomics that evaluates factors as noise and vibration of industrial machinery, and others important aspects as level if luminosity, climatic parameters mentioned above and the presence of inorganic and organic air pollutants mentioned above (UNESCO, 2020). This was originated the health symptoms, and one relevant health symptom mentioned above as ARI, was very important because some expert people that was seek by ARI, was absent to work and some industrial operations not was working and other industrial operations was working with inexpert people in the manufacturing areas, which caused lot quantity of errors and for this reason was fabricated a lot defective product (Tettey et al, 2017). This was concerned to supervision, manager and directive people, which was working with the improvement continuous constantly to avoid this great quantity of errors by inexpert workers of industrial processes (Maleki, 2011).

**Electronics industry**

This is an important type of industry in the world because manufacture a lot products that are used by persons in any place of the world. This industry fabricates a lor products as cell phones, televisions, computers, radios, microwaves, refrigerators, stove and a great quantity of electronic parts to automobile, aircrafts, industrial activities, health equipment and devices, and others electronic systems that are used daily in any place of the world (G. Lopez-Badilla

et al, 2012). As this type of industry manufactures any type of electronic devices to the daily life, and use some metallic materials as aluminum, gold, silver, tin, essentially; have a great disadvantage, because the metallic connections of the electronic devices, can be suffered of the oxidation process and can be operate inadequately or in some times not operate. This can occur in the electrical connectors or connections and this operative yielding decrease very fast (G Lopez et al, 2007)

**Environmental ergonomics factors**

This area of the ergonomics, has been very important in the last ten years, because has controlled aspects as the noise and vibration of industrial machinery, and also the adequate level of luminosity, climatic factors (relative humidity and temperature), and the air pollution that damage the indoor environments of the industrial plants, specially of the electronics industry (Ahmed et al, 2021). In the Mexicali and Tijuana cities are a lot quantity of industrial companies from some countries, being principally of United States, China, Japan, France, England, Netherlands and Italy, essentially. Also, this both cities have a lot quantity of vehicles as cars and motorcycles, and this increase the pollution levels very fast, specially in winter by the greenhouse effect, being a relevant aspect to cause the ARI, and increase fast the persons seek by this health symptom. In this investigation was evaluated the five aspects mentioned above and related with the generation of ARI and other type of health symptom as eye sight problems by inadequate level of luminosity, exposition to air polluted environments in indoors of the ten electronics industries evaluated and use a lot periods of the computer (Díaz-López et al, 2021; Mattia et al, 2016).

**Climatic and environmental factors**

These important parameters have a great influence in the generation of health symptoms mentioned above in the workers of the manufacturing processes, causing a lack of control in the elaboration of the industrial activities (Vanos, 2014). In both cities the mayor effect is represented by the temperature and the presence of the inorganic air pollutants as sulfurs, nitrogen oxides and carbon monoxide, provided from the traffic vehicle and industries that dump pollutants into soil, water and air; and its compounds are exposed to the global atmosphere to cause the respiratory diseases. The inadequate control of this environmental factors generates discomfort in the workers of manufacturing arears, where also, some industrial process can increase the temperature (Kubba, 2014). This is relevant, especially in the Mexicali city where the ranges of temperature can be higher than 40 °C in summer (in the July and August months of every year) and less o 10 °C, which cause very fast discomfort and in some times any health symptom (Belmonte et al, 2021).

**Operative yielding of manufacturing workers**

This relevant aspect has an influence in the fulfillment of the goals of the productivity and quality levels in each industrial company. In this investigation was made an analysis of the operative yielding of each worker of the manufacturing areas (Mumovic et al, 2009). This analysis represented the quantity of manufactured products and the defective products fabricated by some periods as hourly, daily, weekly, monthly, seasonally and yearly. Once this analysis was obtained, specialized people as processes engineers in joint with supervisors and managers; was made some continuous improvements to avoid errors of workers and increase the manufactured products and with this increase the productivity and quality levels (Turunen et al, 2014).

**Productivity and quality levels**

These important aspects in the industrial activities, represents the efficacy of the fulfillment of the goals in each manufacturing areas, which includes the efficacy of workers and machinery, and also the flow of the industrial processes that it must be fluid to reach the goals (Parsons, 2000). These relevant factors generates a lot interest of the directive, managers and supervision people because is the guide to the economical costs and increase of sales of each industrial company.

## 2. METHODOLOGY

In this investigation was made some activities to determine the effect of the environmental ergonomics in the operative yielding of the workers of the manufacturing areas and with this the evaluation of the productivity and quality levels, The activities are mentioned next

a) Analysis of noise and vibrations of industrial machinery. Was elaborated to detect the levels of the noise and vibrations caused by the industrial machinery in the ten electronics industries evaluated and with this generate a continuous improvement to reduce or eliminate these factors. To this activity was used the Sonometer as a measurement equipment Ut353 to measure from 30 dB to 130 dB; and to the vibration factor was used the vibration measurement Monoaxial FLUKE 805FC. And about the international standards to the noise was used the NOM-AA-62-1978 ACUSTICA, and to the vibration was used the ISO10816-3 and the ANSI 10816.

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b) Evaluation of luminosity. Was made to determine the level adequate to maintain in optimal conditions the eye sight of persons that make the industrial operations. In this step was used the digital measurement equipment luxmeter HER408 Steren to determine the quantity of lumen required to some activities as manual operons in a manufacturing cell annexed to the industrial process flow as linear flow. The quantity of lumen was regulated by the NOM 025 STPS 2008 by the Mexican institution called Secretaria del Trabajo, where indicate the quantity necessary to work in some activities as the mentioned above to avoid any health symptom in sight and headache of workers of the manufacturing areas. The standard quantity of lumen is 375 Lux.

c) Analysis of climatic factors. Was realized to detect the climatic levels that had a negative effect in the discomfort, pain or generation of health symptom as the ARI.

d) Evaluation of micropollution. Was elaborated to determine the type of inorganic and organics pollutants that had a negative effect in the health of persons that make his activities in the manufacturing areas of the electronic industries evaluated in this investigation.

## 3. RESULTS

The numerical data obtained was very important to determine the impact that generated the environmental ergonomics factors in the health of people, which works in the industrial processes of the ten electronics industries evaluated. In the next sections are expressed the results of this scientific study.

**Analysis of noise and vibrations of industrial machinery**

This step of the investigation was made to evaluate the ranges of the noise and vibration generated by the industrial machinery, and originated for the movements of his mechanisms, when it elaborates the industrial operations. The numerical data of this analysis is expressed in table 1 (without the continuous improvement) y 2 (after the continuous improvement).

Table 1. Analysis of noise and vibration levels in indoor of the electronics industries evaluated without the continuo s improvement in Mexicali and Tijuana cities (2018)

| Levels (Industry 1) | High Effect | | | | Moderate Effect | | | | Low Effect | | | | No have Effect | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Factors | A | B | C | D | A | B | C | D | A | B | C | D | A | B | C | D |
| Noise | 103 | 96 | 100 | 109 | 98 | 92 | 95 | 101 | 93 | 88 | 90 | 96 | 84 | 80 | 82 | 85 |
| Vibration | 4.2 | 4.0 | 4.1 | 4.4 | 4.0 | 3.8 | 3.9 | 4.1 | 3.7 | 3.6 | 3.8 | 3.9 | 3.0 | 3.3 | 3.2 | 3.4 |
| Levels (Industry 2) | High Effect | | | | Moderate Effect | | | | Low Effect | | | | No have Effect | | | |
| Factors | A | B | C | D | A | B | C | D | A | B | C | D | A | B | C | D |
| Noise | 105 | 99 | 107 | 112 | 100 | 95 | 101 | 102 | 95 | 90 | 94 | 97 | 82 | 81 | 83 | 84 |
| Vibration | 4.6 | 4.3 | 4.2 | 4.5 | 4.1 | 4.0 | 3.7 | 4.2 | 3.8 | 3.6 | 3.7 | 3.8 | 3.2 | 3.1 | 3.3 | 3.3 |
| Levels (Industry 3) | High Effect | | | | Moderate Effect | | | | Low Effect | | | | No have Effect | | | |
| Factors | A | B | C | D | A | B | C | D | A | B | C | D | A | B | C | D |
| Noise | 99 | 98 | 97 | 95 | 97 | 96 | 93 | 98 | 94 | 92 | 93 | 95 | 81 | 83 | 84 | 85 |
| Vibration | 4.0 | 3.9 | 4.1 | 4.3 | 4.1 | 3.9 | 3.7 | 4.2 | 3.6 | 3.6 | 3.7 | 3.8 | 2.9 | 3.0 | 3.1 | 3.2 |
| Levels (Industry 4) | High Effect | | | | Moderate Effect | | | | Low Effect | | | | No have Effect | | | |
| Factors | A | B | C | D | A | B | C | D | A | B | C | D | A | B | C | D |
| Noise | 101 | 100 | 99 | 104 | 98 | 92 | 95 | 101 | 91 | 90 | 94 | 95 | 82 | 81 | 83 | 84 |
| Vibration | 4.1 | 4.1 | 4.2 | 4.3 | 3.9 | 3.8 | 3.8 | 4.0 | 3.6 | 3.7 | 3.7 | 3.8 | 3.2 | 3.2 | 3.3 | 3.4 |
| Levels (Industry 5) | High Effect | | | | Moderate Effect | | | | Low Effect | | | | No have Effect | | | |
| Factors | A | B | C | D | A | B | C | D | A | B | C | D | A | B | C | D |
| Noise | 100 | 98 | 99 | 102 | 96 | 94 | 93 | 99 | 90 | 89 | 91 | 93 | 82 | 83 | 84 | 82 |
| Vibration | 4.0 | 4.1 | 3.9 | 4.2 | 3.8 | 3.6 | 3.7 | 3.9 | 3.6 | 3.6 | 3.7 | 3.8 | 2.8 | 3.1 | 3.0 | 3.3 |
| Levels (Industry 6) | High Effect | | | | Moderate Effect | | | | Low Effect | | | | No have Effect | | | |
| Factors | A | B | C | D | A | B | C | D | A | B | C | D | A | B | C | D |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Noise | 93 | 93 | 94 | 95 | 92 | 92 | 91 | 94 | 90 | 89 | 90 | 92 | 80 | 79 | 81 | 82 |
| Vibration | 4.0 | 3.9 | 4.0 | 4.2 | 3.5 | 3.7 | 3.6 | 3.8 | 3.6 | 3.6 | 3.7 | 3.8 | 3.1 | 3.2 | 3.1 | 3.4 |
| Levels (Industry 7) | High Effect | | | | Moderate Effect | | | | Low Effect | | | | No have Effect | | | |
| Factors | A | B | C | D | A | B | C | D | A | B | C | D | A | B | C | D |
| Noise | 99 | 97 | 98 | 99 | 93 | 92 | 90 | 91 | 88 | 87 | 86 | 90 | 82 | 81 | 80 | 82 |
| Vibration | 4.1 | 3.8 | 4.0 | 4.3 | 3.8 | 3.7 | 3.7 | 3.9 | 3.7 | 3.6 | 3.6 | 3.8 | 3.2 | 3.1 | 3.0 | 3.3 |
| Levels (Industry 8) | High Effect | | | | Moderate Effect | | | | Low Effect | | | | No have Effect | | | |
| Factors | A | B | C | D | A | B | C | D | A | B | C | D | A | B | C | D |
| Noise | 98 | 97 | 95 | 99 | 94 | 94 | 92 | 95 | 88 | 87 | 86 | 90 | 82 | 80 | 80 | 83 |
| Vibration | 4.0 | 3.9 | 4.0 | 4.2 | 3.5 | 3.7 | 3.6 | 3.8 | 3.7 | 3.6 | 3.7 | 3.8 | 3.1 | 3.2 | 3.1 | 3.4 |
| Levels (Industry 9) | High Effect | | | | Moderate Effect | | | | Low Effect | | | | No have Effect | | | |
| Factors | A | B | C | D | A | B | C | D | A | B | C | D | A | B | C | D |
| Noise | 100 | 99 | 98 | 103 | 96 | 95 | 96 | 99 | 92 | 91 | 90 | 94 | 81 | 80 | 82 | 83 |
| Vibration | 4.2 | 4.0 | 4.1 | 4.3 | 3.7 | 3.8 | 3.6 | 3.9 | 3.6 | 3.7 | 3.7 | 3.8 | 3.0 | 3.1 | 3.0 | 3.3 |
| Levels (Industry 10) | High Effect | | | | Moderate Effect | | | | Low Effect | | | | No have Effect | | | |
| Factors | A | B | C | D | A | B | C | D | A | B | C | D | A | B | C | D |
| Noise | 99 | 98 | 98 | 102 | 95 | 94 | 94 | 98 | 92 | 90 | 91 | 94 | 78 | 80 | 81 | 83 |
| Vibration | 4.2 | 4.0 | 4.1 | 4.4 | 3.7 | 3.6 | 3.7 | 3.9 | 3.7 | 3.7 | 3.6 | 3.9 | 3.0 | 3.1 | 3.3 | 3.4 |

Seasons: A. Spring B. Summer C. Autumn D. Winter // The Maximum Level of Noise Permitted by the World Health organization (WHO) in 8 hours is 85 dB (decibels) // Maximum Level of Vibration in Industrial Machinery is 3.5 mm/s (millimeters per second, regulated by the ANSI 10816 Standard.

Table 1 shows the representative values of the noise and vibration generated by the industrial machinery, in the periods of the manufacturing process in the ten electronics industries evaluated, where the period of the work daily has three shifts (Shift1. 6AM to 2PM, Shift 2.2PM to 10PM and Shift 3. 10PM to AM). In the Shift1, the period of time is from Monday to Saturday, in the Shift2 from Monday to Saturday (from 2PM to 7PM) and the Shift3 is only Monday to Friday (10PM to 6AM). The majorly of the values in the first three columns the numerical data obtained, are higher than the standard that is 85 dB and the last column is less of the standard. The numerical data higher than the standard, were presented in the majorly of the periods of the time from daily, weekly, monthly, seasonally and yearly; in the 2018, when the investigation began. An important aspect was that in the winter season to any type of level (high effect, moderate effect, low effect and not have any effect); because in this season the noise and vibrations remain for more periods of times, considering that the windows and doors are closed than in other seasons when the windows and doors are open and in summer, especially in the Mexicali city are closed the windows and doors by the air-conditioning operation, but in this investigation can be observed that in this season, he noise and vibrations decreased as comparative analysis with the winter season, where the noise and vibrations are enclosed. In the next two years of the scientific study, the levels of noise and vibrations decreased, because was applied an automatized device, which was used to detect and control the noise and vibrations of industrial machinery. Also, was reorganized the plant distribution of the ten electronics industries where were made the investigation directed to some exits of the buildings of the ten companies evaluated, and with the automatized system was detected very fast the increase of noise and vibrations of the industrial machinery, Also, this automatize system, send a signal of alert to a computer, and then send a signal to activate a noise absorber with ten wooden plates with sponges collocated in roof and walls of the buildings of the industrial companies where was made this scientific study. This system is in the patent process, so little information is expressed. The automatized system is described in figure 1.


Figure 1 Automatized system to detect and control noise and vibration of industrial machinery

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The automatized system illustrated in figure 1, is a representative device to detect the noise and vibration levels higher than the standard indices, and elaborate an activity to control these relevant factors of the environmental ergonomics, with the activation of an operation to open and close some structure of wooden plates with sponges to reduce the noise and vibration levels. The figure 2 shows a representative operation to mitigate the noise and vibrations. The woody plates turn to left or right to open and close, to reduce the noise and vibrations of the industrial machinery of the ten electronics industries evaluated.

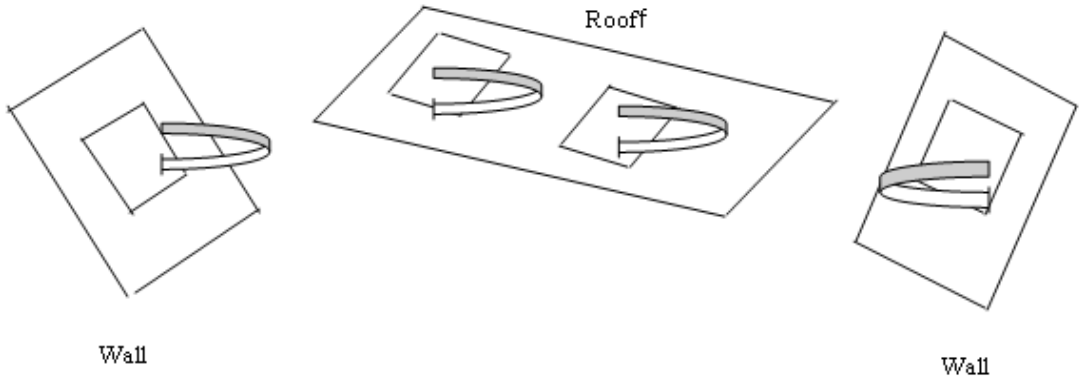


Figure 2. Wooden plate with sponges to mitigate the noise and vibrations of industrial machinery

Once the continuous improvement of the wooden frames with sponge was elaborated and applied, the analysis of the noise and vibration levels of industrial machinery was elaborated again in 2020, observing a decrease in the levels and with it a better comfort of the workers in the manufacturing areas of the ten companies evaluated. The numerical data of the noise and vibrations levels of the ten electronic industries where was made the investigation, are presented in table 2. These values were reduced using the continuous improvement of the woody plates with sponges' system, and the effect on the health of people that works in the manufacturing areas was less.

Table 2. Analysis of noise and vibration levels in indoor of the electronics industries evaluated with the continuous improvement in Mexicali (2019)

| Levels (Industry 1) | High Effect | | | | Moderate Effect | | | | Low Effect | | | | No have Effect | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Factors | A | B | C | D | A | B | C | D | A | B | C | D | A | B | C | D |
| Noise | 78 | 74 | 76 | 80 | 73 | 72 | 70 | 75 | 68 | 66 | 69 | 73 | 62 | 68 | 66 | 69 |
| Vibration | 2.6 | 2.3 | 2.4 | 2.9 | 2.2 | 2.1 | 2.2 | 2.5 | 2.0 | 2.0 | 2.3 | 2.4 | 2.0 | 2.0 | 2.1 | 2.3 |
| Levels (Industry 2) | High Effect | | | | Moderate Effect | | | | Low Effect | | | | No have Effect | | | |
| Factors | A | B | C | D | A | B | C | D | A | B | C | D | A | B | C | D |
| Noise | 74 | 76 | 77 | 79 | 72 | 74 | 75 | 78 | 70 | 69 | 65 | 66 | 65 | 64 | 63 | 67 |
| Vibration | 2.9 | 2.6 | 2.5 | 3.2 | 2.4 | 2.2 | 2.4 | 2.5 | 2.2 | 2.3 | 2.1 | 2.4 | 2.1 | 2.1 | 2.0 | 2.3 |
| Levels (Industry 3) | High Effect | | | | Moderate Effect | | | | Low Effect | | | | No have Effect | | | |
| Factors | A | B | C | D | A | B | C | D | A | B | C | D | A | B | C | D |
| Noise | 75 | 78 | 74 | 80 | 74 | 72 | 73 | 76 | 70 | 69 | 68 | 74 | 67 | 65 | 63 | 70 |
| Vibration | 2.7 | 2.5 | 2.6 | 2.8 | 2.5 | 2.3 | 2.2 | 2.5 | 2.3 | 2.1 | 2.1 | 2.4 | 2.1 | 2.0 | 2.0 | 2.2 |
| Levels (Industry 4) | High Effect | | | | Moderate Effect | | | | Low Effect | | | | No have Effect | | | |
| Factors | A | B | C | D | A | B | C | D | A | B | C | D | A | B | C | D |
| Noise | 76 | 77 | 74 | 79 | 74 | 74 | 72 | 76 | 72 | 70 | 70 | 75 | 68 | 67 | 69 | 73 |
| Vibration | 2.8 | 2.9 | 2.7 | 3.0 | 2.5 | 2.6 | 2.3 | 2.8 | 2.1 | 2.4 | 2.2 | 2.5 | 2.0 | 2.2 | 2.1 | 2.4 |
| Levels (Industry 5) | High Effect | | | | Moderate Effect | | | | Low Effect | | | | No have Effect | | | |
| Factors | A | B | C | D | A | B | C | D | A | B | C | D | A | B | C | D |
| Noise | 76 | 73 | 75 | 77 | 73 | 72 | 72 | 75 | 70 | 67 | 68 | 75 | 63 | 62 | 60 | 64 |
| Vibration | 2.8 | 2.5 | 2.3 | 2.6 | 2.2 | 2.2 | 2.3 | 2.4 | 2.0 | 2.1 | 2.2 | 2.3 | 2.0 | 2.1 | 2.1 | 2.3 |
| Levels (Industry 6) | High Effect | | | | Moderate Effect | | | | Low Effect | | | | No have Effect | | | |

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| Factors | A | B | C | D | A | B | C | D | A | B | C | D | A | B | C | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Noise | 77 | 75 | 76 | 79 | 74 | 73 | 73 | 74 | 72 | 71 | 71 | 72 | 70 | 68 | 69 | 70 |
| Vibration | 2.6 | 2.5 | 2.6 | 2.8 | 2.3 | 2.4 | 2.4 | 2.5 | 2.2 | 2.2 | 2.3 | 2.4 | 2.1 | 2.0 | 2.1 | 2.5 |
| Levels (Industry 7) | High Effect | | | | Moderate Effect | | | | Low Effect | | | | No have Effect | | | |
| Factors | A | B | C | D | A | B | C | D | A | B | C | D | A | B | C | D |
| Noise | 77 | 79 | 75 | 82 | 74 | 75 | 73 | 77 | 71 | 72 | 73 | 75 | 70 | 74 | 71 | 72 |
| Vibration | 3.1 | 3.0 | 3.0 | 3.3 | 2.8 | 2.7 | 2.6 | 3.0 | 2.6 | 2.5 | 2.3 | 2.5 | 2.3 | 2.2 | 2.1 | 2.4 |
| Levels (Industry 8) | High Effect | | | | Moderate Effect | | | | Low Effect | | | | No have Effect | | | |
| Factors | A | B | C | D | A | B | C | D | A | B | C | D | A | B | C | D |
| Noise | 79 | 81 | 80 | 85 | 74 | 76 | 77 | 80 | 73 | 72 | 73 | 75 | 71 | 72 | 70 | 73 |
| Vibration | 2.7 | 2.8 | 2.5 | 2.6 | 2.4 | 2.2 | 2.3 | 2.5 | 2.1 | 2.2 | 2.3 | 2.4 | 2.0 | 2.1 | 2.2 | 2.3 |
| Levels (Industry 9) | High Effect | | | | Moderate Effect | | | | Low Effect | | | | No have Effect | | | |
| Factors | A | B | C | D | A | B | C | D | A | B | C | D | A | B | C | D |
| Noise | 75 | 77 | 74 | 79 | 74 | 75 | 73 | 75 | 73 | 73 | 72 | 74 | 70 | 71 | 72 | 73 |
| Vibration | 2,5 | 2.6 | 2.5 | 2.7 | 2.4 | 2.2 | 2.3 | 2.5 | 2.3 | 2.1 | 2.2 | 2.4 | 2.1 | 2.2 | 2.1 | 2.3 |
| Levels (Industry 10) | High Effect | | | | Moderate Effect | | | | Low Effect | | | | No have Effect | | | |
| Factors | A | B | C | D | A | B | C | D | A | B | C | D | A | B | C | D |
| Noise | 78 | 75 | 77 | 79 | 75 | 74 | 75 | 77 | 73 | 73 | 72 | 75 | 69 | 67 | 70 | 73 |
| Vibration | 2.7 | 2.6 | 2.4 | 2.9 | 2.4 | 2.3 | 2.3 | 2.5 | 2.2 | 2.4 | 2.1 | 2.2 | 2.0 | 2.1 | 2.0 | 2.3 |

Seasons: A. Spring B. Summer C. Autumn D. Winter // The Maximum Level of Noise Permitted by the World Health organization (WHO) in 8 hours is 85 dB (decibels) // Maximum Level of Vibration in Industrial Machinery is 3.5 mm/s (millimeters per second, regulated by the ANSI 10816 Standard.

Table 2 shows the representative values of the noise and vibration of industrial machinery of the ten electronics industries evaluated, where can observe that were reduced when was applied the woody plates with sponges' system. The analysis of the tables 1 and 2, were in the Mexicali and Tijuana cities, where the first industrial companies (from 1 to 5) evaluated are in the Mexicali city and next industrial plants (from 6 to 10) are in Tijuana.

**Evaluation of luminosity**

In this step was made an evaluation of the luminosity in some industrial operations as a manufacturing cell, which are next to the industrial process flow considered as linear flow, and are necessary some specific operations as manual activities and require the luminosity adequate. For this reason, an analysis of the correlation of luminosity and the generation of sight problems in workers that were making these manual operations. This represented in figure 2.

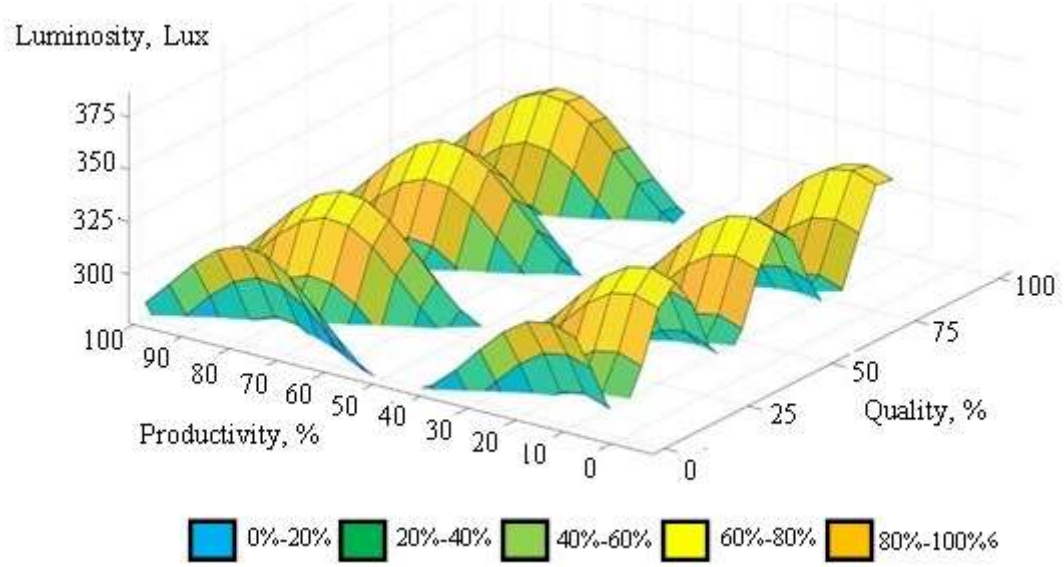


Figure 3 Correlation analysis of the luminosity and productivity and quality levels (2018-2020) in Mexicali

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Figure 3 illustrates the correlation analysis of the luminosity as environmental ergonomics factor and the productivity and quality levels as the production aspects, which are determine the economic aspects of any industrial company in any place of the world. S is showed in the figure, the colors represent the grade of correlation (from 0% to 100%, as total correlation), where in each color is presented a section of the total correlation. This was illustrated the period of the 2018 to 2020 (with some strict regulations by the presence of the Covid 19 pandemic), where is presented that in 2018 year, with the correlation was low (in general maximum correlation of 35%), observing with the colors in blue and dark green. Then was illustrated the correlation of the 2019 year, with the correlation as moderate (from 35% to 85% of correlation), showed in light green and yellow colors in the last section of this evaluation was the period of the 2020 year. In the 2020-year period of this analysis, was presented the orange color, representing the maximum grade of the correlation analysis, where was presented the major productivity and quality indices. In according, to the increase of the correlation grade, was increased the productivity and quality levels, and with this can be assigned that have a good correlation between the parameters included. For increase the correlation grade was necessary change the distribution plant of some industrial processes. This correlation analysis was in the Mexicali city, and in Tijuana was almost the same correlation grade, for this is presented only this evaluation, but in the Mexicali, which the city with the major effect than in the Tijuana city.

**Analysis of climatic and pollution factors**

This was important factor in the environmental ergonomics evaluation because in some periods of the year during this scientific study, the temperature and relative humidity presented variations that was generating discomfort and headache to the operative personnel, which works in the manufacturing areas. The climatic factors mentioned above, originating a negative effect in the productivity and quality levels, but was influenced with more grade in the productivity index, because was observing that the quantity of products fabricated decreed in the begin of this investigation. This was involved in this correlation analysis with the variations of relative humidity and temperature.

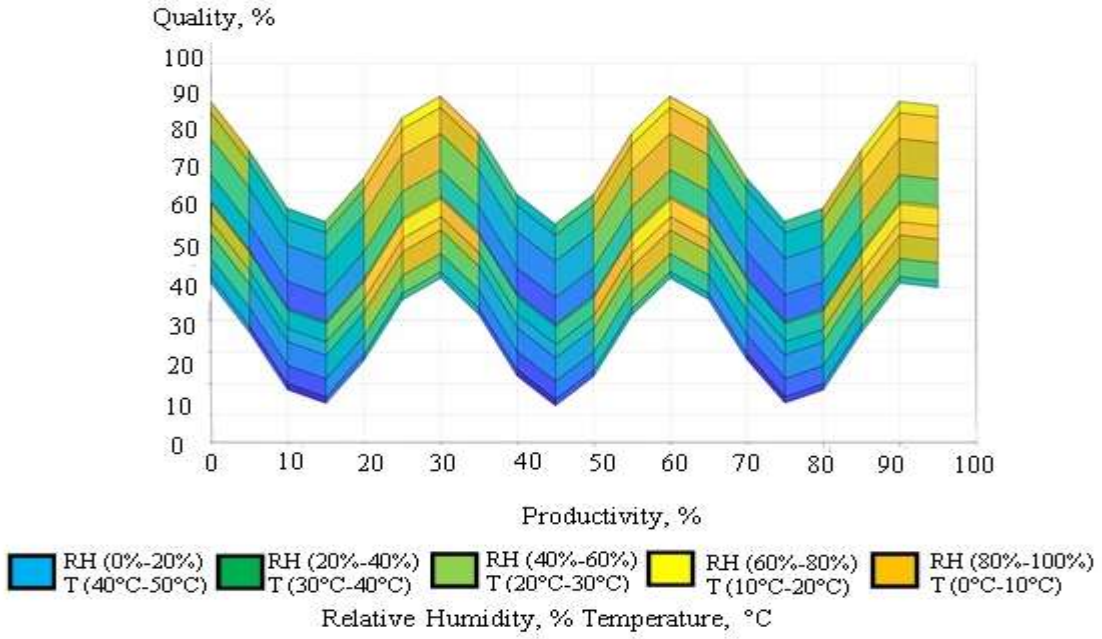


Figure 4 Correlation analysis of the climatic factors and productivity and quality levels (2018-2020) in Mexicali

Figure 4 shows the correlation analysis of the climatic parameters as environmental ergonomics factors corelated with the productivity and quality levels. This part of the scientific study was relevant because in according to the increase or decrease of these climatic factors, was generated the ARI (based in the changes of temperate and humidity in summer and winter), where in summer the relative humidity in the Mexicali city was very high principally in the July and August months of each year evaluated. This evaluation was in the Mexicali city because had more effect the climatic factors in the operative yielding of workers of the manufacturing aeras and with this with the productivity and quality levels. This was illustrated the period of the 2018 to 2020 (with some strict regulations by the presence of the Covid 19 pandemic), where is presented that in 2018 year, with the correlation was low (in general maximum correlation of 30%), observing with the colors in blue and dark green. Then was illustrated the correlation of the 2019 year, with the correlation as moderate (from 30% to 80% of correlation), showed in light green and yellow colors in the last section of this evaluation was the period of the 2020 year. In the 2020-year period of this analysis, was

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presented the orange color, representing the maximum grade of the correlation analysis, where was presented the major productivity and quality indices.

**Microevaluation of air pollution in indoor of the electronics industry**

One relevant aspect of the environmental ergonomics was the microevaluaton of the air pollutants, where was observed in microphotographs the presence of the microorganisms in each industrial company evaluated. In this analysis was observed that in figure 5 the presence of microorganisms by percentage as is hosed in the figure with different colors, where from electronics industry 1 that is showed as number 1 in the right and bottom section as light blue and the smallest size. Then is illustrated a industrial company 2 and others companies with diverse colors and sizes as is showed from 1 to 5, represented the electronics industries in the Mexicali city and 6 to 10 the industrial companies in the Tijuana city. As is illustrated in the diverse colors and sizes, which is showed that in the industrial plants located in the Tijuana city, the sizes are more bigger the sizes of the industrial companies in the Mexicali city, indicating that in Tijuana the presence of microorganisms are more as around 100% in the industrial company 10, that is showed in the microphotography with the presence of the virus of influence type A to generate the ARI. This was because in the Tijuana city presented values of relative humidity higher than in the Mexicali city, for the coastal zone that generate a lot humidity I every time of the year.

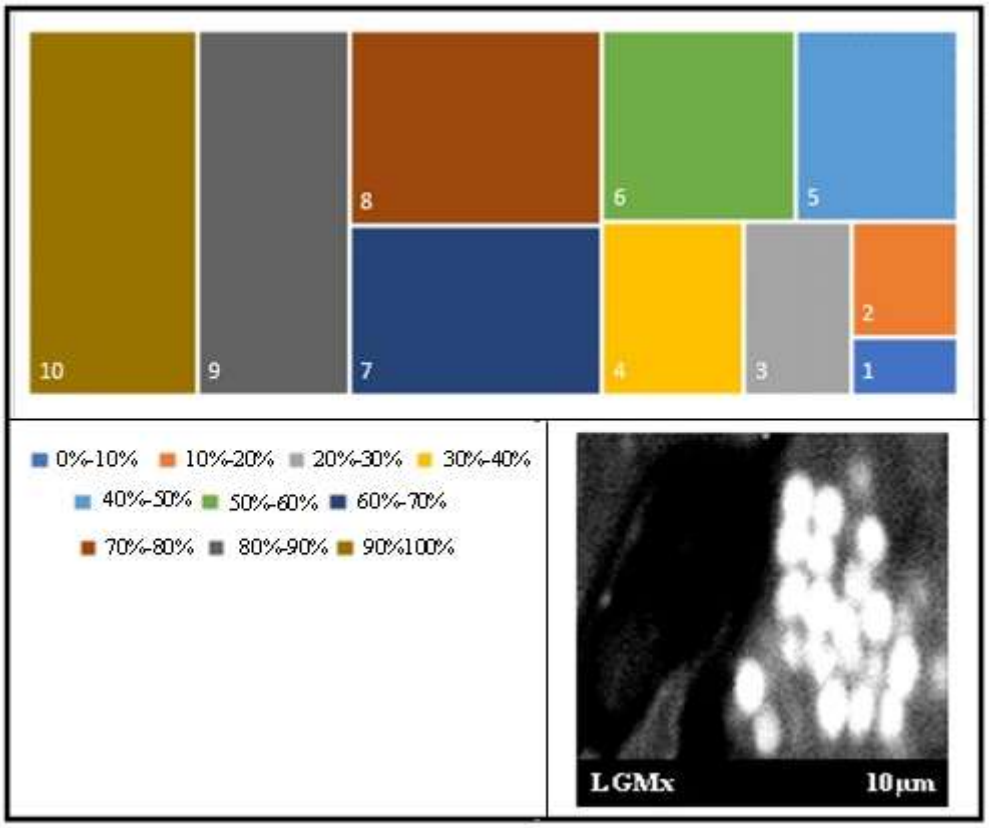


Figure 5 Correlation analysis of presences of microorganisms and microphotography of the virus of influence type A

## 4. CONCLUSIONS

The environmental ergonomics factors are very relevant in the operative yielding of workers than elaborate the activities in the manufacturing areas, and wit this sometimes some electronics industries can't reach the goals proposed in a period of time of the industrial activities. In this investigation was observed that the climatic factors (relative humidity and temperature), noise and vibration of the industrial machinery, and the presence of air pollutants and microorganisms that generate the ARI, were relevant aspects, which originate a decrease of the productivity and quality levels at begin of this scientific study. The correlation analyses elaborated shows the real situation in the ten electronics industries (located five in the Mexicali city and the other five are in the Tijuana city), observing that the lack of attention of this environmental ergonomics in the industrial companies evaluated. The directive, managers and supervision people were concerned and were working to apply the continuous improvement to improve the productivity and quality levels and to avoid the generation of ARI in people of the manufacturing areas, which were reduce its operative yielding. The evaluation respect of the difference of the both cities about the humidity is important

because with this environmental ergonomics factor can generate the ARI in the workers, being an important aspect of the decrease of the operative yielding.

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