



Correlation Analysis of the Effect of PM_{2.5} in the Generation of Heart Diseases in Workers of the Electronics Industry of Mexicali, Baja California, Mexico

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Abstract – The health organization and industrial association of Mexicali, which is one of cities more contaminated of the Mexican Republic, considers that heart disease is the main cause of death in the people that works in manufacturing areas of an electronics industry located in this city. One of the relevant factors of this serious health symptom is exposure to polluting particles from chemical agents (derived from sulfur (SO_x), nitrogen (NO_x) and carbon (CO), coming from the large vehicular traffic in this region of Mexico, in addition to other types of agents such as cat hair, soot (from burning cardboard, tires and wood), mainly in the winter season to mitigate the low temperatures in this city, as well as pollen the spring period, and biological microorganisms and fungal spores from plants and fungi that affect the health of the people of this city. Based on this, an investigation was made to correlate the effect caused by exposure to PM_{2.5} particles (particles less than 2.5 microns in diameter), of the agents mentioned above, in the generation of cardiovascular diseases. PM_{2.5} was evaluated, because according to the environmental authorities of the Mexicali city, it is the main polluting agent and that it is in the outdoors atmospheres, which can penetrate to the indoors environments. This pollution agent can enter to indoors of buildings, through small cracks, crevices or holes and roof and can be penetrate to human body through the respiratory ducts and can be deposited in the lungs. This can generate bad function of lungs and cause the generation of cardiovascular diseases in this desertic city of our country, which is a border region with the United States, essentially with the California state. In this scientific study, clinical evaluations were

made (information of heart diseases from 2017 to 2021), variations of relative humidity (%) and temperature (°C), as well as analysis of polluting agents at the macro and microscopic level (with the scanning electron microscopy–MBE technique). This investigation was made from 2017 to 2021, including the period of the Covid19 pandemic, which increased the incidence of cardiovascular diseases in the population of Mexicali.

Keywords: Air pollution, PM_{2.5}, cardiovascular diseases, climatic factors.

1. INTRODUCTION

This investigation represents the relationship that generated the incidence of cardiovascular diseases in workers of manufacturing areas of an electronic industry located in the Mexicali city, and was caused by exposure to various diverse types of agents shown in figure 1, represented by biological agents (mushroom spores), chemicals (SO_x, NO_x, CO), physical agents (dust) and tiny particles such as PM_{2.5} (less than 2.5 microns) and PM₁₀ (less than 10 microns), which is a mixture of biological, physical and chemical agents of the aforementioned size.

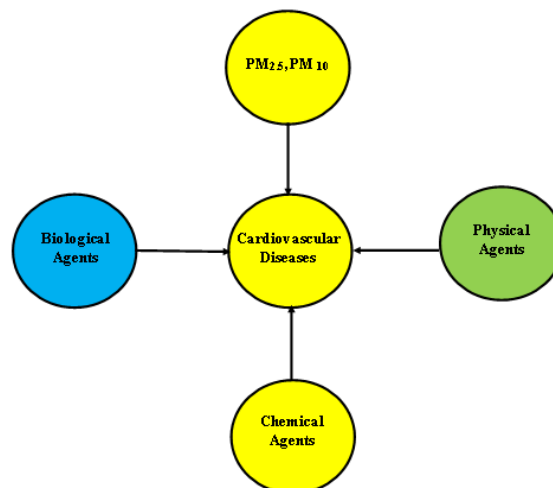


Fig -1: Pollution agents that generate cardiovascular diseases in Mexicali city (2021)

Source: Analysis of the investigation

As is showed in figure 1, the agents described in this illustration and mentioned above, generated the cardiovascular diseases, being caused by the four types of agents showed in this figure. These four agents were caused principally by the traffic vehicle and industrial companies that dump industrial waste on the ground, and that spread in outdoors atmospheres of these industries, remaining these agents suspended for various periods of time. These suspended particles enter to indoors of buildings through cracks, holes, crevices, and roofs, originating in the electronic industry where was made the investigation, the incidence of cardiovascular diseases in workers, due to the generation of respiratory diseases and labor stress in the workers of the manufacturing areas.

1.1 Electronics Industry in Mexicali

The electronics industry is very important in the world because a lot of devices and equipments used in the real life by a lot people, are manufactured in this type of industry, and lot electronic systems are used in other type of industries as aerospace, agricultural, biomedical, food and beverage, metallic, plastics and textile industries. In this industry are fabricated diverse products being the best know cell phones, computers, microwaves, tablets, and televisions; where is utilized the linear flow to manufactures great quantity of products, being able generates great quantity of errors if the linear flow is uncontrolled. Also, some specific electronic devices, systems and equipments can suffer of damage because have specialized sections that overpass the limit about electrical current or voltage, can be, or are exposed to aggressive environments as the chemical agents mentioned above, can generates the corrosion phenomenon, and originate bad function as well as the persons when suffer of any type of respiratory and consequently of cardiovascular diseases. In this type of industry works a lot persons that are exposed to the agent mentioned above and generates the health symptoms mentioned above, principally the cardiovascular diseases, which originates a great concern, as both in the industrial company whereas made the investigation, because decrease the operative yielding of the workers and the productivity and quality levels, as the concern is also in the health authorities of Mexicali city, and state (Baja California) and national authorities (Mexican Republic), for the enormous expense that is generated.

1.2 Environmental Pollution

Is caused by the lack of awareness of persons that release contaminants in the form of solids, gases, or liquids into the atmosphere as in various types of soils worldwide, aquifers at ground level such as rivers, lakes, seas or a certain depth such as wells or caves; In addition to discharging into the air substances such as the chemical agents mentioned above or tobacco smoke, among the most relevant. For this reason, we are damaged our planet, occasioning every day the climatic crisis, and can generated consequences as the presence of diseases, essentially the respiratory diseases and consequently the cardiovascular symptoms. Exist two types of contamination, being the first the natural originated by the natural agents and particles provided from nature. In figure 2 is represented the three principal natural agents of the natural pollution in the Mexicali city.

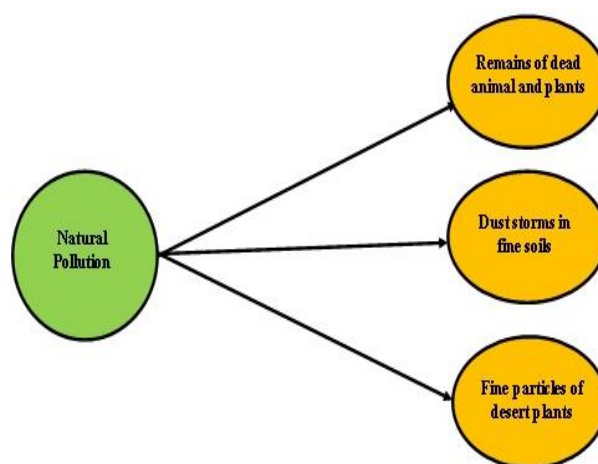


Fig -2: Natural agents of pollution in the Mexicali city (2021).

Source: Analysis of the investigation

Figure 2 shows the natural agents generated in the Mexicali city, which are relevant in the origination of respiratory symptoms and consequently in the cardiovascular diseases, being a factor in the environmental pollution that caused the health symptoms mentioned above. The first agent (remains of dead animals and plants) was a little significant effect in the health of workers where was made the investigation, because are a bit remains in the zone where is located the electronics industry where was made the scientific study. The second and third agent was very important because Mexicali is a desertic zone with fine particles of dust and when occurs the dust storms (considered as physical agents), was generate the respiratory diseases and consequently the cardiovascular symptoms. Also, was evaluated the anthropogenic sources that are near of the electronics industry where was made the scientific study in the Mexicali city and is showed in figure 3.

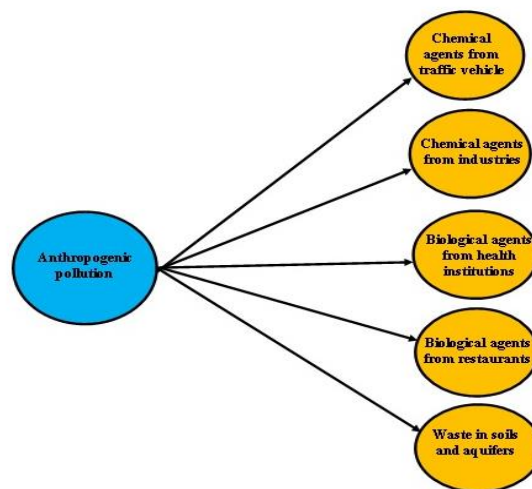


Fig -3:Anthropogenic agents of pollution in the Mexicali city (2021).

Source: Analysis of the investigation

Figure 3 illustrates the five principal anthropogenic sources observed near of the industrial company where was made the investigation. The first agent was the traffic vehicle, because this electronics industry is located near a boulevard where transit a lot of quantity of cars, principally from Monday to Friday, where a lot people need pass for this zone of the Mexicali city, because need to go your jobs. A lot of motor vehicles in this border city are old (20 years old) and the majorly persons with low socioeconomical level, not make the maintenance of your cars, provoking the air pollution of the chemical agents mentioned above. The second agent was generated by the uncontrolled polluted gases from near industrial companies (metallic industries that use sulfuric acid and nitrogen acid to its industrial processes), of the electronics industry where was made the scientific study. The principal gases were the derivates of sulfur and nitrogen. The third agent was considered as the biological pollutants from a big hospital, where in sometimes of the year dump biological waste, even when health and environmental authorities know this and allow it. The four agent is same of the third, but the biological waste is from three restaurants near of the industrial company where was made the investigation, being the same aspect with the health and environment authorities of this city.

1.3 Climatic Parameters

These parameters were very important in this investigation because had a negative effect in the generation of the respiratory diseases and consequently in the cardiovascular symptoms, essentially in the winter seasons where temperatures where low (from 5°C to 10°C), provoking problems to breath in some persons, specially of old people, where are around 35% of the total population of the Mexicali city (have around 1000000 of population). Also, other factor of the climatic parameters evaluated was the relative humidity, which in periods of summer with values higher of 40%, some people as diabetic, obesity and cardiovascular symptoms that are around 50% of this city as is mentioned in the annual statistical report of 2021 of the Mexicali authorities of health institutions. In the period of summer, essentially in the months of July and August, the people with the health symptoms mentioned above suffer and can be breath normally and need medical assistance. These climatic parameters added to the wind flow and velocity in some times at 5 km/hr., can disperse the pollution agents and increase the quantity of persons with cardiovascular diseases.

1.4 Cardiovascular Diseases

These health symptoms are very relevant in any person, because can generate serious symptoms and sometimes can occur the death very fast. These types of diseases are increased in the last five years in the Mexicali for the exposition of the air pollution in this city that is one of the ten cities with more contamination levels in the Mexican Republic. This type of health symptom is caused by other organs of the human body as lung, liver and kidneys, essentially. The bad function of the organs mentioned cause health complications in the heart and for this reason the death when the complications are very serious. In figure 4 is represented the principal factors of the generation of cardiovascular diseases.

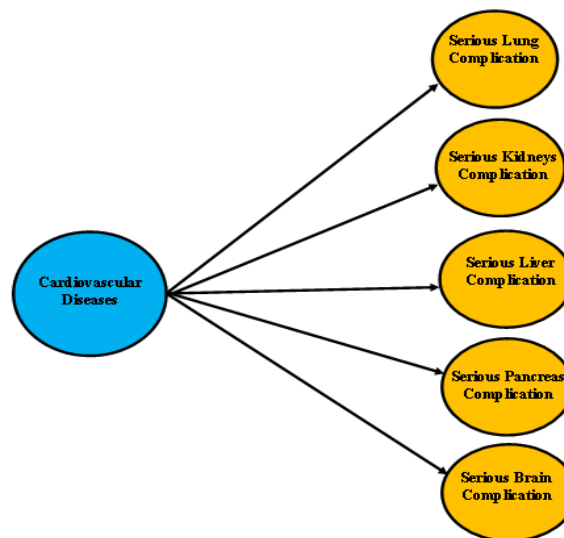


Fig -4:Principal organs that generated cardiovascular diseases in Mexicali city (2021).

Source: Analysis of the Investigation

Figure 4 shows the five principal factors referred to human organs that caused the cardiovascular diseases in the Mexicali city, where was observed that these human organs caused the health symptoms of the heart. The first organ with major complication was the lung organ, which have the function of interchange



air flow to breath and with this the blood flow that pass for the heart. The second organ that originated health complications was the kidneys, because have the function to clean the blood that pass for the heart, being the third organ the liver, which generates complication in the heart because have the function of control the fat of the human body to avoid that the veins and arteries attached to the heart are blocked. The four organ that caused complications in the hear during this investigation was the pancreas because is a relevant organ in the metabolism of the body, and where is consequence the excess of sugar, causing the diabetes. The five organ that produced health complication was the brain, when was a serious bifunction for exposition at temperatures and relative humidity higher than 45 °C and 50%.

2. METHODOLOGY

This investigation was made to determine the grade of effect generated by the exposition of air pollutants and variations of climatic parameters in the generation of health symptoms of some organs of the human body and originated the cardiovascular diseases in the workers of an electronics industry located in the Mexicali city. This scientific study was made in three steps that are expressed now:

- a) **Evaluation of air pollution and climatic factors:** In this step, was made an evaluation of the pollution and climatic factors to determine the principal pollution and climatic agent with major effect in the generation of the cardiovascular diseases in the electronics industry evaluated. In this step was used the air quality analyzer Aeroqual Series 500.
- b) **Analysis of Cardiovascular diseases:** In this step, was made an analysis of the principal human organs that were affected by the air pollution and provoked the cardiovascular diseases.
- c) **Microanalysis:** This step was detecting some microorganisms with a plastic plate of 1 cm X 1cm, showing relevant results. In this step was used the FEI Tecnai F20.

3. RESULTS

This investigation represents a relation of the exposition to air pollution and the variations of climatic factors as expressed in the next sections.

3.1 Correlation Analysis of Air Pollution and Cardiovascular Diseases

In this section of the investigation was made a correlation analysis of the SO₂ and the incidence of cardiovascular diseases as is showed in figure 5, where is observed that the majorly of black color (1-73%), but in some zones of the graph have some big points, indicating the correlation analysis grade, with different colors as dark blue (1-3%), green (1-3%), light blue (3-9%), orange (2-6%), purple (1-3%) and yellow (1-3%). The number in parenthesis indicates the times of appearance of each color, followed by the percentage of each color represented in the graph. The graph meanings that from 0.3 ppm to 0.8 ppm of SO₂, had an influence in the generation of cardiovascular diseases, being at 0.5 ppm with the major effect. This means that the correlation grade was of 84%, being a big factor to determine the relation of the exposition of air pollutants, principally of PM_{2.5} in the generation of cardiovascular diseases.

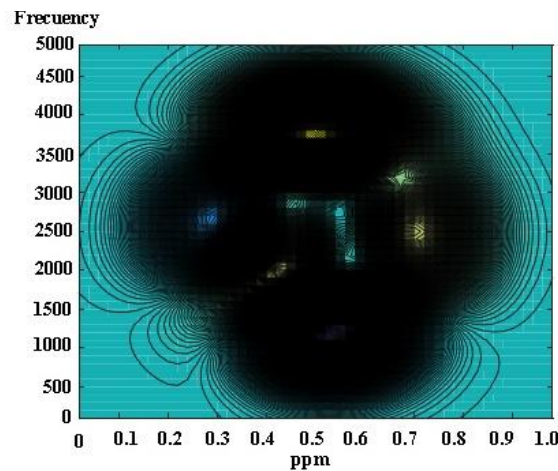


Fig -5:Correlation analysis of SO₂ and incidence of cardiovascular diseases (2021)

3.2 Control of Environmental Factors

The air pollution was evaluated to determine the grade of correlation between air pollutants and the climatic, observing that the SO₂ was the air pollutant that overpass the air quality standards in all periods of the analysis from 2020 and 2021. A relevant aspect evaluated was the decrease of the air quality levels from 2020 to 2021, because was made three principal actions: (1) reorganized the distribution plant (all industrial plants), (2) installation air filters to detect and not permit pass gases and particles to avoid the presence in indoor of polluted gases and particles as PM_{2.5} and (3) use automatized systems to control temperature and relative humidity to not generate changes in this climate that originate health symptoms as respiratory symptoms and consequently cardiovascular diseases. This is represented in table 1.

Table -1: Analysis of environmental factors in indoor of the electronics industry evaluated (2020–2021)

Environmental Factors	Temperature, °C				Relative Humidity, %			
	SO ₂	NO ₂	CO	PM _{2.5}	SO _x	NO ₂	CO	PM _{2.5}
2020								
Spring	0.79	112	13	43	0.81	115	15	47
Summer	0.66	105	10	39	0.70	110	11	43
Autumn	0.87	123	15	46	0.90	138	17	50
Winter	0.97	134	18	51	0.99	147	21	55
2021								
Spring	0.59	102	10	36	0.59	110	13	40
Summer	0.52	98	8	32	0.55	103	10	37
Autumn	0.68	107	11	39	0.72	111	14	43
Winter	0.76	118	13	42	0.79	122	16	46

Air Quality Standards. SO₂-0.5ppm at 1 hour, NO₂-100 ppb at 1-hour, CO-9ppm at 7 hours, PM_{2.5}-35µg/m³ at 24 hours

3.3 Generation of Cardiovascular Diseases by Pollution Factors

In this part of the investigation, was made an evaluation of the generation of the cardiovascular diseases from 2017 to 2021. One aspect of importance was that 2017 to 2019 before the presence of the Covid9, was observed a decrement of the incidence of the cardiovascular diseases, but from 2020 to 2021, was illustrated an increment by the presence of the Covid19 pandemic.

Table -2:Correlation of pollution factors and incidence of cardiovascular diseases (2017–2021)

Pollution Factors	SO ₂	NO ₂	CO	PM _{2.5}
Year				
2017	612	534	524	689
2018	587	513	516	645
2019	534	501	498	621
2020	789	589	528	899
2021	743	567	554	865

3.4 Microanalysis of Polluting Agents

To detect the presence of Aspergillus Fumigatus, it was necessary to carry out a test of respiratory secretion (sputum) in 20 workers who presented respiratory symptoms and a microanalysis was made with the scanning electron microscopy (MBE) technique, shown in figure 6, an appearance of the formation of Aspergillus Fumigatus at a scale of 100 μm (a) and 1μm (b), showing the presence of this biological contaminating agent illustrated in figure 6, which led several people from the manufacturing areas of the company to be evaluated.

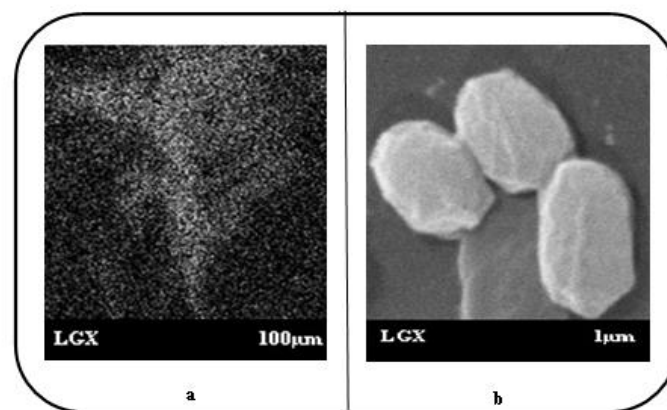


Fig -6:Aspergillus Fumigate with less of 2.5 micra of diameter as cologne (a) and individually (b) that caused respiratory diseases and consequently cardiovascular diseases in workers of manufacturing aeras of an electronics industry of Mexicali city evaluated (2021)

Figure 2 shows in section (a) as microphotography at 100 μ m, observing the formation of a cologne of *Aspergillus Fumigata* developed in a plastic small plate (1 cm X 1cm) of five plastic small plates installed in strategic places at 2 meters of height of an area of the manufacturing processes of the industrial company evaluated. The section (b) represents at 1 μ m, a microphotography of the presence of the agent *Aspergillus Fumigata* with more precision of its development. This caused the Aspergilosis disease, originating that the *Aspergillus Fumigata* penetrates to the conductive respiratory and are deposited in the lungs, causing a health symptom of cardiovascular diseases in the workers of the industrial plant evaluated.

CONCLUSIONS

In this scientific study was observed the correlation level of the exposition to the pollution agents mentioned above, which in some periods of the investigation, showing the major effect specially in the winter season of each year evaluated, the generation of the respiratory diseases and consequently the origination of the cardiovascular diseases. The main air pollutant was the PM_{2.5}, which is a mix of chemical, physical and biological agents at less of 2.5 micra. The improvement actions of the redistribution of the industrial process in the electronics industry, using specialized filters of gases and very small particles avoid the penetration of these air pollutants from the outdoor provided from different sources, to indoor of the industrial company was made the scientific study. This study was one of the first investigations in the Mexicali city, including the PM_{2.5} as pollution agent.

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